Solar Combi+

Identification of most promising market and promotion of standardized system configuration for the market entry of small scale combined solar heating & cooling applications

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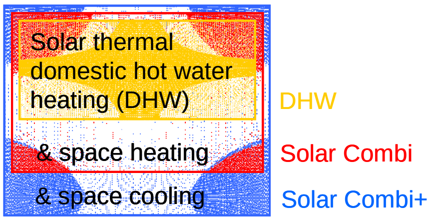
1 Introduction

The aim of this project was to take newly commercially available small scale sorption chillers and identify and promote standardized **Solar Combi+** systems for small applications (residential and office buildings, up to a cooling demand of 20kW).



The most critical barriers to a broad application of SolarCombi+ systems are:

- Combined solar heating & cooling needs high effort in design stage, which is not affordable for small applications.
    - Standard system configurations were identified and promoted. They will reduce the design effort for single applications considerably and they are the basis for the development of package solutions by the participating sorption chiller producers.
- Small scale sorption chillers are expensive as production volumes are currently low.
    - Most promising markets were identified, which might trigger the application of technology and initiate economies of scale.
- The concept of small scale combined solar heating and cooling is not well known by traditional small scale solar thermal installers, planners, architects and potential clients.
    - Tailored dissemination plans included, among other measures, the training of solar thermal installers, targeted presentations to professionals, information of the public in most promising regions as well as advice to policy makers and promotion of pilot plant installation to public authorities.

To identify the above standard system configurations and most promising applications, the project performed a numerical analysis starting from promising system configurations (based on a thorough analysis of the market) validated by economical and ecological ratings for different typical conditions (i.e. utilization, climate, building type).

Now it is the right moment to support the market entry of SolarCombi+ with reliable dimensioning and a comprehensive analysis of promising applications. In this way the spread of Solar Combi+ can go hand in hand with the buildup of important solar thermal markets for e.g. Spain, France Greece, Italy and the southern new member states.

To proactively encourage the market entry of this technology, producers of small scale sorption chillers were involved in the project, playing the role of primary target group and also being key actors for the implementation of the project results. They were therefore active partners in the project and gave major inputs to its structure and implementation. Producers of small scale chillers, which are not directly involved, benefit from the project as the standard system configurations are a starting point for them to develop their own package solution too.

Professionals and professionals' groups as traditional small scale solar thermal installers, but also HVAC planners, architects and engineers were the second major target group for Solar Combi+. During the project implementation, professional groups were informed of opportunities related to the Solar Combi+ systems, standard system configurations and package solutions through contacts with national and international interest groups, presentations in occasion of events organized by other related national and international projects, fairs and conferences. An online accessible database of standard configurations performance was also made available to this purpose.

Policy makers, national and regional authorities as well as solar thermal enterprises responsible for support programs, implementation and recast of EPBD were also contacted.

Potential consumers which ask for Solar Combi+ were the most important target group for triggering pull market. Their needs, habits and willingness to use Solar Combi+ systems were therefore analyzed within the market analysis. A complete SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) was also performed.

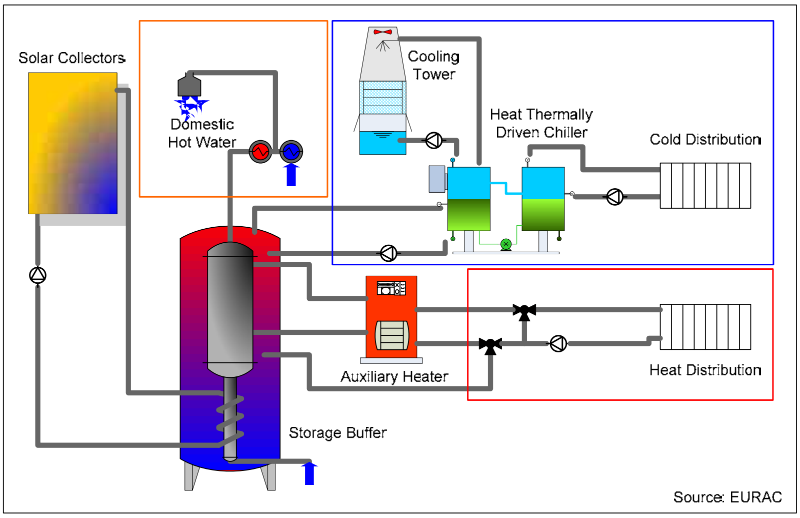
2 Summary

The need to ensure high level of indoor comfort has resulted in a market increase in sales of equipment for winter and summer air conditioning of buildings. Index of an increased standard of living is also the large increase of electrical energy consumption in recent years in the residential sector across Europe, which is actually responsible for more than 40% of total energy consumption [1]. A survey of 15 European Union countries also identified for the summer conditioning electricity consumption of about 90TWh, of which 33TWh attributable to Spain, 27TWh to Italy and 10TWh to France [2].

In recent years, solar energy has also found application in systems for the production of cold water (sorption machines) for air-conditioning, applications encouraged mainly by simultaneity between high solar radiation and cooling demand. These machines can be effectively incorporated into so called solar combi plus systems, in which solar energy is used to produce domestic hot water and for both space heating and cooling. Thermal driven sorption chillers were up to now only manufactured in the high power range (>100 kW_{cold}). Today, machines with rated power between 5 and $30kW_{cold}$ are available to be included in solar combi+ systems for small applications, which make up for the major part of heating and a constantly growing part of cooling demand.

2.1 The Technology

Solar combi plus systems use heat from solar thermal collectors to provide heating in winter, cooling in summer and domestic hot water (DHW) all year round. Figure 1 sketches the main components in a typical system.



Source: EURAC

Figure 1 - Typical setup of a solar combi plus system

The solar thermal collectors provide the heat usually backed up by an auxiliary heat source; a storage tank can either be installed on the hot side, as shown in the figure, on the cold side or on both; a domestic hot water preparation unit; the sorption chiller is fed with hot water (70-100°C): heat rejection at intermediate temperature (30-40°C) to a cooling tower (dry or wet) or another heat sink (e.g. a swimming pool); the cold distribution system (e.g. a chilled ceiling, fan-coils or air handling units) and the heat distribution system (preferably a low temperature system).

There are several different collector technologies available on the market. Which technology is best suited for a particular application depends on the needed operation temperature. For solar combi plus systems, there are 4 relevant temperature levels:

- 40°C for a low temperature space heating system
- 60°C for domestic hot water preparation
- 70°C typical driving temperature for adsorption chillers
- 90°C typical driving temperature for absorption chillers

The efficiency curves of different collector models should now be compared at the highest necessary temperature level. Figure 2 shows efficiency curves for three collector technologies.

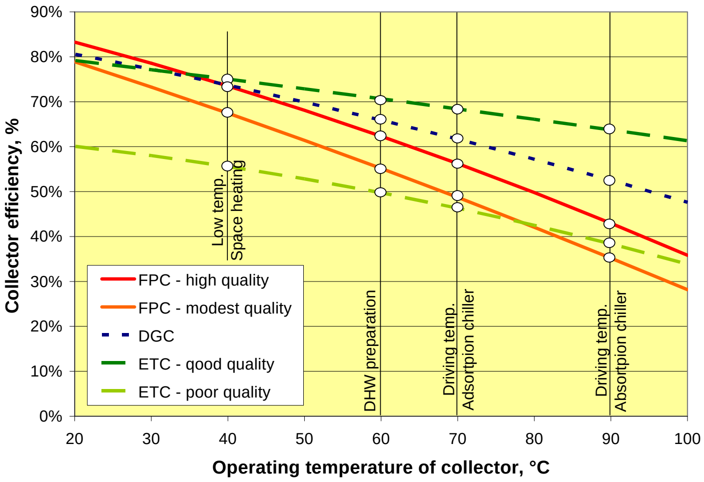


Figure 2 - Typical collector efficiency curves based on aperture area of different collector types (FPC – Flat plate collector, DGC – Double glazed collector, ETC – Evacuated tube collector). Assumptions: 800 W/m² global radiation at normal incidence and an ambient temperature of 20°C.

The first thing to notice is that there are very different qualities on the market. The red and orange curves show a typical good quality flat plate collector and a modest quality one respectively. For evacuated tube collectors the range of qualities is even larger. In between these technologies, double glazed collectors have recently entered the market.

Those are basically flat plate collectors with an additional glass cover or Teflon foil to reduce heat losses from the collector.

Figure 3: Flat plate collectors (picture source: Sonnenklima)

At low temperatures (as necessary for a low temperature space heating system) the differences in efficiency between the different collector technologies are relatively small (except for poor quality evacuated tube collectors which are not suitable for this application). However, the more the operating temperature increases the more important a good quality collector becomes. Evacuated tube collectors typically have the smallest heat losses and are therefore best suited for high temperature applications. However, even among evacuated tube collectors, it is important to pay attention to install a high quality collector. On the other hand, good quality flat plate collectors or double glazed collectors can in many cases almost keep up with evacuated tube collectors. It may be worth to install a slightly larger surface area of double glazed or flat plate collectors instead of investing in possibly significantly more expensive good quality evacuated tube collectors. For each particular application, annual simulations are recommended in order to identify the best collector technology for the needed temperature level and available radiation.

Figure 4: Evacuated tube collectors at Venice Marina (picture source: Climatewell)

2.2 The Project

Costs of the investment and lack of experience of designers and installers are the most important barriers for a broad diffusion of solar combi+ applications. The assessment of standard system configurations might reduce considerably the design effort for single applications and is the basis for the development of package solutions possibly manufactured at a large scale level.

The project Solar Combi+ had the goal of identifying a limited number of configurations for solar combi plus systems featuring cooling capacity up to 20 kW. The project involved five industrial partners, manufacturers of sorption machines (Sortech, Climatewell, Fagor / Rotartica, SOLution, SonnenKlima), and seven research partners (EURAC, Tecsol, AEE-INTEC, Ikerlan, CRES, University of Bergamo, Fraunhofer-ISE).

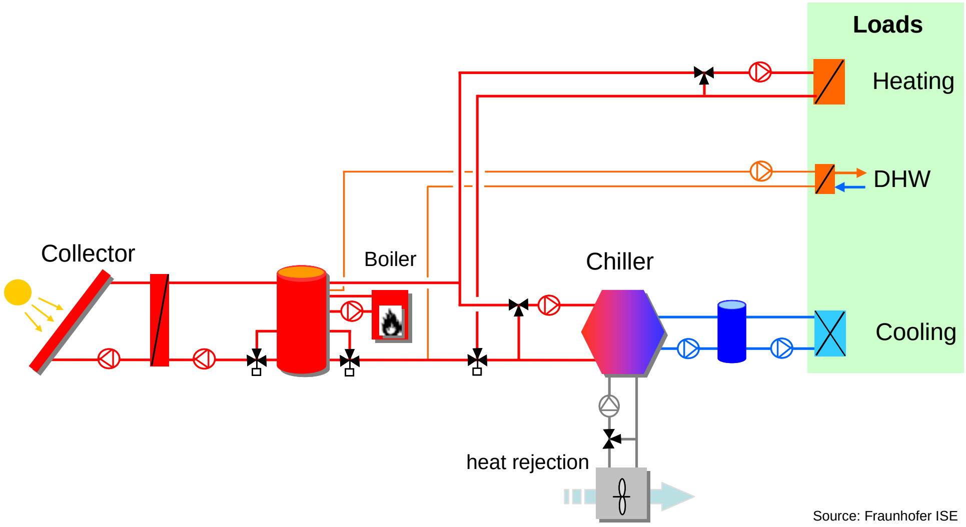
The study started with a market analysis carried out in two steps. In a first phase the markets for Solar Combi+ were analyzed in depth by providing information on the chiller market, solar thermal market and consumer behavior, and - most important - detailed information on cost of the single components. The market research was made on three pillars: (i) small scale chillers, (ii) solar thermal applications, (iii) consumers. The analysis was based on Eurobarometer reports, specific research and questionnaires toward the actors of the air conditioning sector. Markets analyzed were primarily the partner's countries (Italy, Spain, Greece, Germany, Portugal, France, Austria). Moreover an economic analysis of the systems provided significant outcomes concerning the current competitiveness of solar combi+ compared with other technologies, its future prospects and potentials based on an analysis of its economic viability.

The results from the first phase were the main basis for the definition of the system layouts investigated through numerical simulations carried out in TRNSYS.

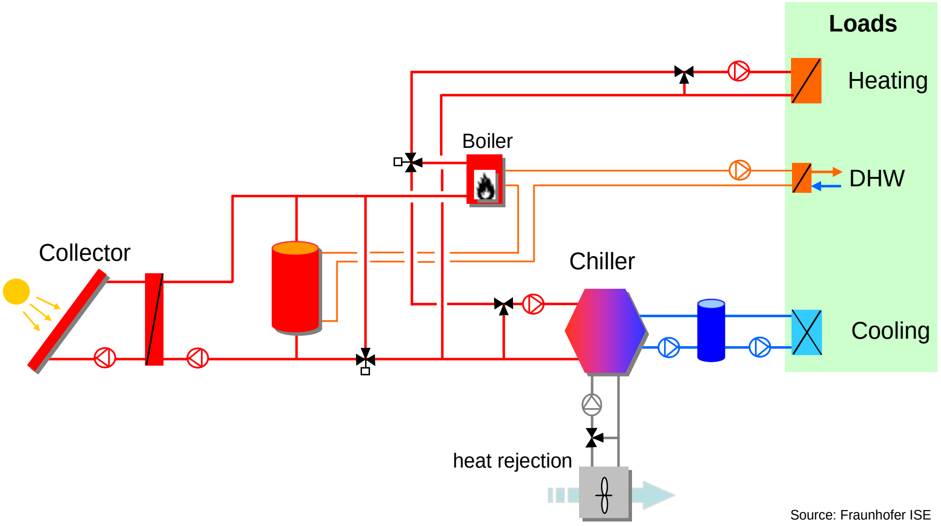
Then again the results from the numerical studies performed were the basis for the SWOT analysis and definition of market goals in the second phase of the market analysis. At the same time, European climatic and market data were compared to define which are the most promising places for a solar combi+ system to be installed.

The two plant configurations defined are shown in Figure 5. The first configuration has a central heat storage tank with different temperature zones for space heating, DHW preparation and driving heat for the chiller. This tank is heated by both the solar thermal collectors and the auxiliary heater. For charging the store from the solar collectors, there is a switching valve that allows drawing the return flow to the collectors either from the middle or from the bottom of the tank. This allows reaching the needed temperature level in the storage tank for driving the chiller more quickly. Similarly, the return flow from the chiller or space heating loop can be fed into the tank at different heights depending on its temperature level. In summer time, energy is drawn from the tank to drive the chiller. For the domestic hot water preparation, an external plate heat exchanger is used. In winter time the energy in the storage tank is used for space heating and DHW preparation.

The second configuration is adapted to the Spanish market where the auxiliary boiler is not allowed to charge the solar heat storage tank. Therefore, the auxiliary boiler is connected in series to the solar heat storage tank.



Source: Fraunhofer ISE



Source: Fraunhofer ISE

Figure 5 – TOP: System configuration with the auxiliary boiler charging the main heat storage tank. BOTTOM: Configuration with the auxiliary boiler in series with the main heat storage tank

An extensive campaign of numerical simulations carried out in TRNSYS was conducted on these configurations, varying a set of design parameters:

- Type of sorption machine
- Application (residential building or office)
- Geographic position of the application (Naples, Toulouse, Strasbourg)
- Distribution system (fan coils or radiant floors/ceilings)
- Type of solar collector (flat-plate collectors or evacuated tubes)
- System for heat rejection (wet, dry or hybrid cooling tower)
- Area of the collectors' field
- Volume of the buffer tank.

With regard to the geographic location, three sites were studied; representative regions characterized by different heating and cooling loads, in particular Naples (Italy), Toulouse (southern France) and Strasbourg (Central France) were considered. Three small size applications were also selected, with different energy requirements in terms of domestic hot water, heating and cooling needs: two residential buildings with different power consumption in summer and winter and a building used for offices. The construction features of buildings and their use being set, the energy consumption was estimated according to the reference climate. Table 1 shows the thermal loads for heating and cooling; as regards the demand for domestic hot water, about 1800 kWh/a for Toulouse and 1600 kWh/a to Naples were established. There was no provision for consumption of hot water in relation to the office application.

Table 1 – thermal loads on the three applications identified. Thermal loads vary depending on climatic conditions

	Office		residential building average loads		residential building low loads	
	Heating kWh/m^2/y	Cooling kWh/m^2/y	Heating kWh/m^2/y	Cooling kWh/m^2/y	Heating kWh/m^2/y	Cooling kWh/m^2/y
Strasbourg	69	34	-	-	-	-
Toulouse	34	50	46	6	25	6
Naples	9	81	21	18	9	18

Because five commercial sorption chillers with different rated power were taken as a reference for the simulations, the size of the buildings was scaled according to their cooling capacity; in this way a fair comparison of systems with different chillers was performed. The area of the collectors and the size of the storage tank were, in turn, scaled according to this parameter: the first parameter was varied between 2 and 5 m^2/kW, while useful values for the second were considered between 25 and 75 liters per unit area of collector.

The combination of all variables described above, led to make about 2500 numerical simulations whose results in terms of energy performance and environmental benefits were used for the selection of a small number of standard system solutions. Among all the calculated parameters, three were taken as reference for this assessment:

- Total Solar Fraction
- Total electric efficiency
- Percentage of primary energy saved annually

The total solar fraction accounts for the percentage of total load (production of hot water, heating and cooling) which is covered by the exploitation of solar energy:

$$\boldsymbol{SF_{tot} = \frac{Sol.\,En._{useful}}{Heating + Cooling. + DHW}}$$

The total electrical efficiency indicates how much electricity is used to cover the total loads:

$$\boldsymbol{Eff_{tot} = \frac{Heating + Cooling. + DHW}{El.\,En._{tot}}}$$

Finally, the percentage of primary energy saved per year allows comparing the total energy consumption related to the solar combi plus system (inclusive of contributions related to the circulation pumps, fans in the heat rejection system, etc.) with those of a traditional reference system:

$$\boldsymbol{PES_{rel} = \frac{PE_{trad} - PE_{SC+}}{PE_{trad}}}$$

2.3 The Results

For each set of variables examined, three best configurations were extracted that maximize each of the benchmarks mentioned.

The analysis shows that the size of *5 m^2/kW and 75 l/m^2 for collectors' field and buffer tank respectively* allow the best performance in all situations considered. These sizes are slightly higher than typically found in solar cooling systems (cooling only environment), in which the area of the collectors is about a 4 m^2/kW; in the case treated, in fact, the winter heating requires the use of greater proportions. Larger areas (up to 7 m^2/kW) would lead to slightly better results, hardly justified because of strongly increased investment costs (+10 ÷ 15%).

In general, plants characterized by *better performance* are those relating to applications where *high solar radiation* is combined with *high summer cooling loads and moderate needs for heating and production of domestic hot water*. *In the most profitable cases, total solar fraction of 80%, together with primary energy savings in the order of 60% were found*.

The parameters that mostly affect the system performance are the type of collectors and the heat rejection system. The *vacuum tubes collectors* allow higher primary energy savings than those obtained with flat plate collectors (*on average +15 ÷ 30%*) due to the higher temperatures achievable. This increase is paid through a substantial increase in investment costs. The study does not demonstrate a clear superiority of a technology for heat rejection on the others. However, it highlights how the *electricity used for running that component can contribute significantly to the energy consumption of the system: an inadequate use of this component compared to the real needs of the system can easily drop out all the energy saving.*

All data on *standard system configurations identified are listed in a database that can be queried online* (http://wis.eurac.edu/solarcombiplus/Default.aspx). The tool, developed to disseminate the findings of the study, allows choosing the climatic zone of the installation, the type of application, the collector type, the distribution and heat rejection system, among those taken into consideration for the simulations. Depending on the choices it makes available the results of simulations in terms of total solar fraction, solar fraction on cooling loads, primary energy savings, solar gain and efficiency of the total electricity consumption. *In this way, the effects of different technological options are easily manageable by professionals and end users as a function of the system size.*

All the investigated locations are suitable under the point of view of the heating needs and potential coverage of the loads through a high fraction of solar energy, due to the low temperatures needed (40°C were considered as heating temperature level). *Southern countries are obviously more suitable for cooling applications due to the significantly higher radiation, which is available, while passive cooling could be a more adequate solution to cover northern countries requirements. However, cooling needs might result much higher too in southern regions, both during the days and the nights.*

The technologies used for cooling (ab-/adsorption chillers) and for harvesting the solar energy have to be considered too: as far as the needed temperature levels go higher and the location moves northern, more effective solar collectors shall be adopted. The extra saving obtained with evacuated tube collectors should always be compared with the extra initial system costs.

Therefore, although *the return of the investment is cut when combined high heating, cooling and DHW loads are encountered*, a “most promising market” cannot be stated within the ones analyzed, since the selection of a good location is so much dependent on the technology employed (both for heating and cooling and for the construction of the buildings). The technology and the economics of the specific application have to be evaluated.

The SWOT analysis showed that the *solar combi+ system is advantageous* in terms of technology, *being an innovative and efficient system, with further prospects of improvement, due to its market entry phase*. Characterized by low electrical consumption and a high total solar fraction, it can effectively compete, in terms of primary energy savings, not only conventional systems but also other sustainable technologies.

The increasing number of installations can play an important role to its further recognition, while the work accomplished within the Solar Combi+ project regarding *the definition of standard system configurations will be the first step for a European/international standardization*.

In terms of cost effectiveness, the technology’s currently *high capital cost is mitigated by lower operating costs with respect to the conventional technologies*. An added value to the economic feasibility of the technology is offered through the various financial incentives currently in force in the European countries and the overall European policy and strategy towards a sustainable future. *However, effort should be still laid in mobilizing the relevant mechanisms for the introduction of new incentives in European level* that offer a distinguishing and specified support to small scaled solar thermal systems, as well as taking advantage of regulations concerning the energy efficiency and sustainability of buildings.

Nevertheless, certain drawbacks of the technology as well as the threats met in the market should be individually addressed as problems.

A *noteworthy issue that somehow hinders the wide penetration of SC+ systems is again related with the fact that each examined system manufactured/sold by the project’s industrial partners has unique technical characteristics influencing its operation, performance, component dimensioning and optimal application/location*. This suggests that, for now, the chillers can be fairly good standardized at technological level (i.e. manufacturer), but they are not easily standardized on market level as a whole. *Further effort should be laid for both enhancing the technology and establishing a wider approval, by installing systems* *that are correctly performing from the very first moment after setup*, as well as by creating economies of scale, identifying competent promotion means and pushing it to the most promising market areas.

3 Conclusions

Main results of the project are related with the technical implementation of solar combi+ applications. Following some recommendations for good design of solar combi+ systems are given:

- **Large Collector Areas Perform Best:** well-sized systems have a collector size of about 4 to 5 m²/kW reference chilling capacity and a hot storage volume of 50 to 75 l/m² collector aperture area. If the system is dimensioned according to this rule of thumb, high total solar fractions can be obtained and the system operates close to the optimum in terms of primary energy savings and the costs of these primary energy savings.

- **Implement Optimized Control Algorithm:** the control strategy influences the performance of the system considerable in terms of both solar fractions and primary energy consumption. That means that an individual adaptation of the system control to the chiller as a function of location, application and configuration offers significant potential for improvement. Especially the control of pumps and the heat rejection fan must be studied.

- **Use Chilled Ceiling Distribution System:** chilled ceiling systems are more favorable compared to fan coil systems in terms of chiller performance due to a higher temperature level in the chilled water circuit. However they are more expensive to install and often more critical to use in heating mode for application in office and residential buildings.

- **Consider Solar Autonomous System for Cooling:** to maximize primary energy savings it should always be considered to design a system without backup for cooling in summer. If a system is designed large enough, solar fractions for cooling can be above 90% and using the backup system for cooling can be avoided. Other options to reduce fossil fuel consumption are to install a biomass boiler or to use waste heat as heat backup system or an electrically driven compression chiller as cold backup. This will increase primary energy savings but also increase investment costs.

Even though the market did not develop significantly during the project implementation since the technology was in a stage of early development when the project began, **standard system configurations** were identified and promoted. The latter, **together with** the above **mentioned SWOT analysis**, helped the sorption chiller producers focusing on the **optimization**

of the design/installation process and the **development of package solutions**. In this way the installations might work properly from the very first moment after setup. **Reliable systems can therefore be promoted effectively on the market both toward final customers and investors - that could support further industrial development of the technology**.

Dedicated incentive schemes have also to be encouraged for the market entry of the solar combi+ technology. As far as a complete standardization is still to be reached, **incentive schemes that partially cover both capital costs and production** have to be pursued, **applied to few initial "good" systems.** The "Emergence" plan recently started in France already acts in this direction; similar schemes should be developed all over the southern European countries.

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5 List of Solar Combi+ Deliverables

The project deliverables are reported at:
http://www.solarcombiplus.eu/Project/deliverables_en.htm

Market Analysis

1. Report on market situation - small scale chillers Report on market situation - solar thermal applications
2. Report on market situation - consumers
3. Report on market situation - cost analysisSWOT Analysis
4. Examination of potential market share and definition of goals

Virtual Case Studies

5. Description of methodology and case studies
6. General results of virtual case studies

Determination of standard applications & most promising markets

7. Report on identification of standard system configurations
8. Description of package solutions Description and Visual Representation of Most Promising Markets
9. Online tool
10. Short info for feasibility studies

Training on Package Solutions

11. Training material to be included in trainings
12. Evaluation report of Training courses campaign

Dissemination and Communication

13. Project leaflets & posters
14. Newsletters
15. Information brochure on standard configurations
16. Support material for EPBD
17. Feasibility Studies
18. References articles & papers

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6 SWOT Analysis and Definition of Goals

The SWOT Analysis is a very common process in strategic planning, providing a framework to categorize a wide range of inputs from technical, financial and other experts in a way that facilitates decision making. SWOT is an acronym for Strengths, Weaknesses, Opportunities and Threats. The SWOT analysis headings provide a good outline for reviewing and assessing the strategy, position and direction of the technology. Moreover, by implementing further techniques such as the SWOT matrix, the outcomes of the SWOT analysis could be incorporated to produce important strategic directions and define goals”.

6.1 Strengths

6.1.1 Technical issues

High electrical COP and high potential for further increase of SC+ system’s efficiency

In general, the electrical COP of the best configurations for solar thermal systems as resulting by the simulation analysis ranges from 11 up to 51. With an average electrical COP of app. 30, it is significantly higher than the respective COP of competing technologies (e.g. the average COP of a heat pump accounts for 3 – 3.5, though if geothermal, it can reach 7). Moreover, when analyzing the viability of a SC+ system, it has to be considered that it is currently at a development stage, while R&D is still ongoing. This suggests that technical improvements are bound to take place, as observed through the market deployment of numerous technologies. The potential for an increase in efficiency (electrical COP, Total Solar Fraction) is rather high and will positively affect SC+ systems’ technical performance.

Compatibility with conventional heating/cooling & existing distribution systems

An important issue is that it is feasible to connect a SC+ system with conventional heating/cooling systems, such as boiler and heat pumps already installed in a building. Moreover, the compatibility with existing distribution systems such as fancoils and chilled ceiling offers an added value to the technology, taking into account that, in other cases where the installation of a new distribution system is requisite, the effort and expenses could be rather burdening.

Extension of the use of existing ST systems (DHW)

One of the major advantages and motivations for implementing a SC+ system to a residential building is the upgrading of existing solar thermal systems that merely provide DHW to a major building energy provider, in order to cover, additionally, the needs for space heating and cooling.

Solar autonomous, base cooling load coverage

In most cases, as proven by the analyses conducted up to now, the SC+ systems is in position to cover the average cooling loads in summer without the need of further committing an auxiliary system. However, this applies mainly to office buildings, where the cooling load period corresponds with the highest irradiation period, and not in domestic buildings, which, furthermore, have a non-negligible requirement for DHW. As resulted from the definition of standard system configurations, the total solar fraction for office applications is significantly higher than the corresponding residential applications for the same climatic regions. For instance, the average total solar fraction of an office application for different configurations reaches 93% in Naples and 81% in Toulouse

Future development of standard design systems

Being one of the main goals of the project, the identification and development of standard design systems will contribute to achieving a highly intensive market deployment, by reducing significantly the design effort for single applications and providing the manufacturers the required information and means for the development of package solutions. In this way, the SC+ system can be promoted and applied in a similar way as the standardized systems for domestic hot water production, which work practically well in common applications and are independent of specific product.

Less losses of transformation from PE to electricity

A technical parameter that should also be considered is the reduction in losses occurred during the transformation of primary energy to electricity, taking place for the operation of other technologies. Solar thermal systems due to the fact that they mainly use thermal energy achieve significant reduction of primary energy conversion losses.

New applications emerging

Due to today’s developing stage of the examined technology, in terms of R&D, new applications are emerging, different than the ones considered so far, allowing for the consideration of innovative ideas and alternative solutions. For instance, it is currently attempted to apply the technology in ships for cooling, where the excess heat of ship engines would be used as supplement or instead of solar irradiation. The chillers will become widely known, even if applied at different circumstances, letting end users become familiar with small scaled chillers and later consider the installation of SC+ systems.

6.1.2 Cost-related parameters

Relatively low operating cost (in off-gas mode: eg, cooling)

One of the main issues that have to be investigated in any developing technology is its economic viability. The most significant parameter for examining it - besides the initial investment - is the operating cost. Renewable energy technologies have the advantage of minimizing the operating cost, which mostly consists of the energy (fuel or electricity) cost. Therefore, one significant parameter of the SC+ systems can be found under the low operating cost when it is operated in off-gas mode.

Almost independent of energy markets

The operating cost consisting mostly of fuel/electricity cost is a major issue affecting consumers' preferences. Furthermore, today's volatile energy markets make it quite impossible for the consumer to predict or estimate the fluctuation of energy prices on a long-term basis. Therefore the technology's independence from energy markets can be effectively used for its market promotion.

6.1.3 Marketing

3-in-1 features: One product solves 3 needs for the user

Marketing may be substantial for the viability of a new technology, which can be successfully promoted if the right aspects are selected. In the case of small-scaled SC+ systems the major marketing-oriented advantage is found under the bundling of multiple functions into one single product. In specific, the user or operator of such a system will profit by covering all his three energy requirements (i.e. heating, cooling and domestic hot water) through only installing one system.

Positive environmental profile – Mitigation of CO2 emissions

A second advantage that can be widely employed as a promotion tool is the environmental profile being developed by the operation of a solar thermal system, in terms of CO2 emissions reduction, saving of primary energy and electricity. The analysis conducted on the simulation results provided the outcome that, in absolute terms, the avoided CO2 emissions range between

2 and 4 tons/year in all case studies. If one bears in mind that the residential building considered could be used by a 4 people family (0.5 to 1 tons CO2 spared each) and that in a typical European city every inhabitant is responsible for around 8 to 10 tons of CO2 emitted per year (transport and economical activities also considered), it can be extracted that the large scale diffusion of SC+ systems would lead to a significant reduction of the CO2 emissions and therefore of the primary energy used. The aforementioned conclusion could be also essential for the promotion of SC+ systems. Particularly when installed in offices, owners/organizations can benefit by its advertising, exhibiting their environmental concerns, through the beneficial results achieved, such as reduction of CO2 emissions and the primary energy savings.

State of art equipment / system

Above all, the SC+ systems are considered to be a state of the art and innovation-based technology. One of the SC+ systems participating in the project has been awarded with a number of distinctions, being also a patented technology. Moreover, the good reputation achieved through further recognitions and awards of both the technology and the management team can significantly strengthen the market position. This could be extended to the rest of the systems as they all share similar principles based on adsorption or absorption chillers. The SC+ technology could be therefore in general promoted as an award winning promising technology.

Production plants location

Certain production plants of SC+ systems are geographically positioned in strategic areas of Europe, in terms of both being able to serve adequately the EU market and taking advantage of the available labor capacity of the region. Strategic position means reduction of transportation costs, higher chances for commercialization and becoming widely known

Existing installation as best practices

For marketing purposes, the already installed SC+ systems may play a significant role in various ways. Apart from just serving as best practices and verifying the gained approval from the consumers' side, they can also indicate the most preferred locations and applications, but also become an inspiration and driving force for relevant consumers.

The participating industrial partners of the SC+ project, sharing their sales/installations history, declared that they have installed approximately 200 SC+ systems until the end of 2008. Figure 6 represents the shares of installations in each country. Spain holds the vast majority (53.5%) and it is followed by Germany, Austria and Italy with shares of 15.5%, 11% and 9% respectively. Some single systems have been installed in other European countries, such as France, Belgium, UK, Switzerland, Sweden and Hungary while others have been installed to countries outside the EU, namely UAE, USA and China.

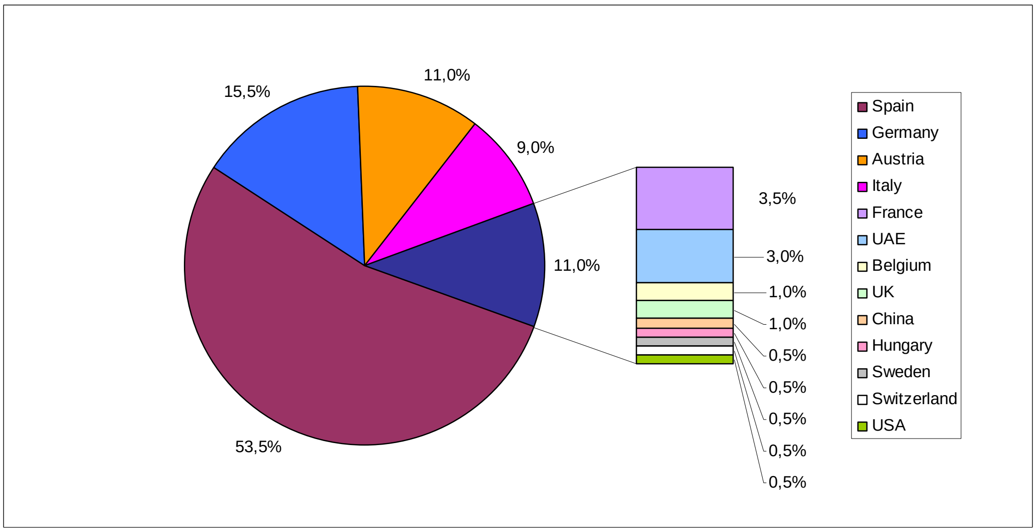


Figure 6: Existing installations by country

Moreover, Figure 7 illustrates the installations in terms of application. Obvious is the preference to office buildings which hold 39.5% for private offices and 2.5% for public buildings. The residential installations for domestic use also hold a significant share with 26.5% of the total installations. Moreover, there have been a number of installations to laboratories, schools, a retirement home, a camping, a medical utility, a sports centre and a university.

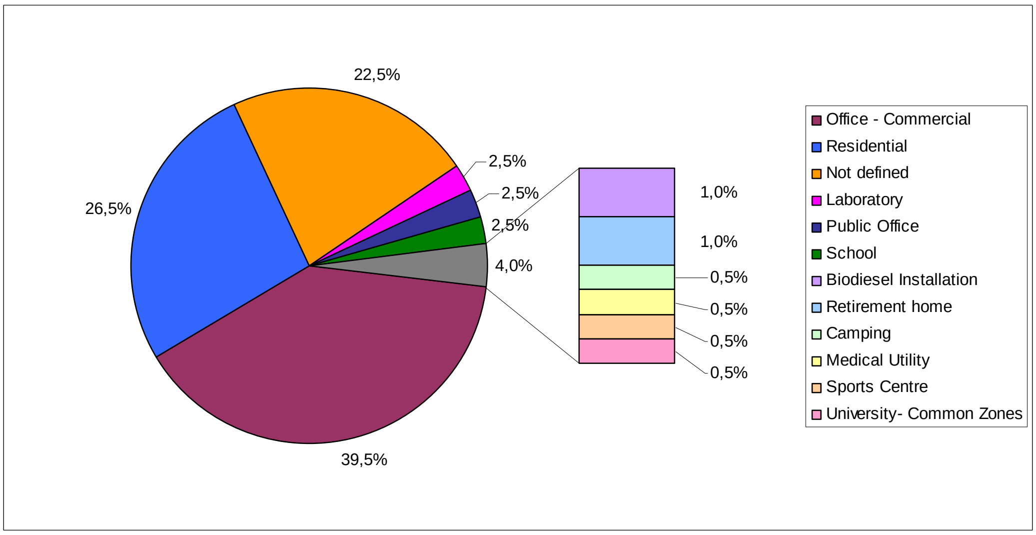


Figure 7: Existing installations by application

6.2 Weaknesses

6.2.1 Technical issues

Storage required

One of the drawbacks of the investigated technology is the requirement on storage for hot water and partially cold water as well. In specific, hot water has to be stored for the hours of the day with no irradiation as well as for low irradiation periods during the year.

Large unoccupied area required

A major issue that can become a barrier for the further development of the market for small scale SC+ systems is the requirement on relatively large unoccupied area. Since the main targets of this technology are single-family houses and small office buildings, it is rather difficult to rely on the fact that such an area will be available.

An auxiliary system required

Probably the main technical drawback of SC+ systems is the fact that they cannot stand alone. As proved through the previous economic analysis, as well as the simulations carried out on various case studies, the SC+ systems are almost always dependent of an auxiliary system, at least for heating and DHW, a fact that reduces the potential for targeting a wider applications area.

Not efficient for all different combinations of location/application

As arisen by the analysis of the virtual cases simulations and the later definition of standard system configurations, the SC+ systems are not efficiently applicable to all combinations of location and application. Some of the best configurations showed somewhat poorer performance in regards with electrical COP. For instance, the average electrical COP of office applications in Naples and Toulouse is 11.5 and 15.9 respectively, which is rather low in comparison with the more promising residential applications reaching the efficiency of 50.

Not standardized and available off-the-shelf yet

Currently the SC+ systems are tailored according to specific needs and no system has yet been developed to be applicable to a series of varying circumstances and requirements. This is also the reason for the high complexity of hydraulics and control of the system, which raises the probability of installation errors or failures during the operation. Moreover, the results of the definition of standard system configurations proved that solutions close to the best ones are not completely product independent when different technologies or component sizes are considered.

6.2.2 Cost-related parameters

High capital cost

As discussed thoroughly in the analysis conducted so far, the SC+ systems are still in a development phase with R&D still playing an important role in the future prospects of the technology and the manufacturing process being based on tailored specifications. A by-consequence of this early market development phase is the rise of manufacturing cost followed by a significant increase in the capital cost, which makes the purchase of such a system very expensive for an initial investment when subsidies are not available. The high capital cost can be, therefore, considered as one of the most significant weaknesses of the examined technology.

No economies of scale

At the moment the production of SC+ is at a very early stage, whereas production plants are barely initiating their operation, a fact that hinders the instant reduction of the long-run average costs of production. This uncertain market in terms of manufacturing cost for SC+ is a significant barrier for the establishment of economies of scale, which would make the technology widely known and applicable.

Relatively high installation and transportation cost

At the moment the systems manufactured at the production plant are distributed to retailers and shifted to the installation site. The lack of local retailers raises the cost for transportation, since at certain cases the systems have to be transported even to different countries. Moreover, since the technology has not been widely approved and developed, no investments have been taken place in terms of training towards both engineers and installers on a local level, a fact that also contributes to an increase of installation cost.

Relatively high maintenance cost

The lack of local retailers also affects issues concerning maintenance. The maintenance cost rises due to lack both of trained on-site personnel, as mentioned previously, as well as procedures like the replacement of parts, which also includes their transportation from distant retailers. In addition to the cost-related drawback for the maintenance of the system, the time frame necessary to conduct the maintaining has to be considered. That is, in case of an unexpected drop out of the system, the period required for the maintenance procedures to be organized and/or the personnel to be shifted onto the site might be longer than expected.

6.2.3 Marketing

Limited operating experience – No reviews and testimonials of existing installations yet

In terms of marketing, a distinguishing weakness is recognized through the lack of operating experience. Although, as already mentioned, there are approximately 200 systems already installed in different locations worldwide (96% of which are inside Europe), the operating period is not long enough for extracting safe conclusions on the system's reliability to become well-known and market-established. Moreover, there has not been any official study yet on their reliability and their achieved performance, based on the owners/operators' experiences. That is, no testimonials have been documented and no official survey has been carried out regarding the customer's/user's satisfaction and the coverage of specific needs. However, the manufacturers/providers of SC+ systems, participating in the project, individually contact their final customers, examining their satisfaction with the operation of the system.

Lack of local retailers

As mentioned previously (see W9, W10), the lack of local retailers, which sometimes even accounts for no presence at all in certain nation-wide markets, is apart from the cost-related issues a major hinder for the successful promotion and market entry of SC+ systems in certain countries.

Limited market applications

Although the machines can be installed in parallel to reach high cooling loads, the fact that the examined technology concerns systems that do not exceed a cooling capacity of 20kW could be a marketing obstacle, since it only explicitly addresses a limited number of applications in the relevant market.

Non-adequately trained technical personnel

Due to the limited market presence of the SC+ systems and the ongoing development of conditions for a successful market entry, there has been no specified training program currently established. That is, the engineers and installers are not thoroughly aware of the varying design parameters and there are no significant provisions of technical support in a local level. Effort is currently given through various IEE projects to enhance the training of specific interested parties, but, nevertheless, there is no ongoing mechanism for the continuous training of the respective technical personnel.

No trademarks currently in force

Although one of the examined SC+ systems already owns a trademark, this does not apply to all systems, which is a consequence of the early market stage of the examined technology. From a marketing point of view, established trademarks would reassure on the technology’s consistency providing significant recognition by the potential clients’ side.

6.3 Opportunities

6.3.1 Technical issues

Locations with good solar irradiation - high cooling loads - high fuel prices

In Europe there are sufficient locations with good solar irradiation (such as the Mediterranean countries) that can be exploited for the development of various technologies using solar energy, among which is also the SC+ systems. Besides, high solar irradiation is usually accompanied by higher temperatures and subsequently growing cooling needs, i.e. a cooling system using solar energy could be fairly efficient for such locations. Moreover, such a technology could compensate the increasing level of fuel and electricity prices that characterize many European countries.

Isolated buildings/regions

The solar technology can be efficiently applied in isolated buildings or regions where the infrastructure does not meet the energy requirements. That is, buildings and regions that are not interconnected to the electricity or natural gas grid or where the transport of oil is carried out with difficulties may profit by installing a SC+ system to achieve energy sufficiency. As already mentioned, a SC+ system can adequately cover the base cooling load without an auxiliary system using fossil fuels, whereas the electricity for the operation of the pumps as well as the coverage of heating and peak cooling load can be completed by relevant renewable energy technologies.

No significant future improvement of fossil-fuel technologies foreseen (efficiency)

A fact that can be used as an opportunity for a more intensive market entry of SC+ systems is the competing technologies' fading prospects in terms of performance. As most of fossil-fueled technologies for heating and cooling have been adequately employed into the market for several years, the right conditions were created for a continuing R&D and implementation of improvements in efficiency, performance and applications. However, as statistically observed, no significant future improvement can be foreseen, as, usually, after having reached a peak, it is rather unlikely to invest on research for an old technology.

Future building integration

Until today, SC+ systems are installed to an existing building, probably even replacing an older heating/cooling system. However, a future ambition, connected to the trends for buildings design and construction procedures, is to integrate the system in the building's planning, so that it can be effectively designed, through the early identification and avoidance of possible technical difficulties or even customization of the building to naturally incorporate the solar system.

Standardization

As for all evolving technologies the standardization is a significant step for a mass market deployment, as the production moves from single customized designs to a standard large-scale level. According to surveys, standards impact 80 percent of world commodity trade being a measure for reliability and success. They furthermore improve competitiveness in global markets and achieve consistent quality, and safety.

Improvement of manufacturing technologies

The technological advancements globally will play a significant role in the improvement of manufacturing technologies, in terms of efficiency, automation and control, which can also be utilized in the SC+ production.

6.3.2 Cost related parameters

Increase in fuel prices

A major opportunity of a renewable energy technology, such as SC+, is the increase in fuel prices. In fact, the minimization of fuel dependency is gaining growing importance in the current energy markets, while fossil fuels and electricity prices are characterized by a constantly increasing tendency. The SC+ systems are not fully independent of fuels (auxiliary system and electricity-driven pumps); however their fuel/electricity consumption is significantly lower than any conventional technology. An increase therefore of the fuel/electricity price would definitely be in favour of SC+ systems.

Cheaper than electric-driven compression chillers

One of the most prominent competitions for SC+ systems is the electric-driven compression chillers. In comparison to them, solar thermal chillers might be cheaper (in terms of operating cost) when the electric infrastructure of a region is not sufficient for electric-driven ones, especially during periods with high electricity demand. For instance, forecasts indicate that in Austria the demand for cooling will rise from 2% today up to 25% in 2025. This might cause electricity infrastructure problems which make SC+ systems more attractive even with a higher installation cost.

6.3.3 Financial incentives

Available financial incentives per country

The availability of financial incentives for the installation of solar thermal systems signifies a very important opportunity for the market promotion of small scaled SC+ systems. It provides a powerful motivation and according to the height and the conditions of each incentive may be the driving force for a successful market deployment.

6.3.4 Market related parameters

Large labour pool available due to recession

A currently important opportunity for the market penetration of SC+ systems is the recent increase of labor pool due to the economic recession. The availability of labor pool will enhance/strengthen the development of manufacturing companies in all the relevant fields of the production procedure, from design to retailing and promotion.

Opening of jobs, businesses, companies - companies - New geographic markets emerging outside the EU.

The further development of SC+ market will be accompanied by a significant opening of new jobs and positions, as well as the establishment of new business and retailing companies. Moreover, exporting SC+ systems to third countries will additionally enhance the economy around this technology, which is a major opportunity to be taken advantage of. As mentioned previously, there have been some installations of SC+ systems also outside the EU with a share of 4%. This already shows an emerging interest from different geographic markets on new technologies, especially those of using renewable energies and it could be an essential opportunity for the reinforcement of the market conditions.

Promotion of sustainability (e.g. UN Climate Change Conference 2009)

In the general energy policy of the European Union, sustainability holds an important role in the priorities set for the achievement of its environmental goals. The constant promotion of sustainability through incentives, communications, guidelines and various projects is affecting considerably the market, leading it to an intensive implementation of environmental-friendlier technologies. Through this change of market direction, SC+ technology can significantly profit highlighting its environmental profile.

“Pioneers” and “front runners” both in green technology and environment protection are looking to invest and buy new technology.

The aforementioned energy policies influence various market stakeholders, who are considered pioneers and front runners in fields such as green technology and climate protection. The SC+ technology may be considered ideal for them, as it combines innovation with an environmental and sustainable profile, making them dominant targets for the market development.

Target specific user’s profile

An important opportunity for SC+ technology is to focus its market opening towards specific user’s profile, where it would have the highest possibilities for wider approval. In specific, applications such as office buildings could profit a lot from installing such a system as it corresponds directly to their specific needs. That is, the heating and cooling load period is normally during the office hours, namely, during the sun irradiation period. Moreover, an office building could save much by not committing an auxiliary system in the summer time, as no demand for DHW is normally foreseen.

6.3.5 Legislation

EU (or national) -Legislation (particularly public sector) for the employment of RES.

A major opportunity for small-scaled SC+ systems applies to the enactment of a legislative framework concerning energy efficiency as well as the employment of renewable energy sources in certain fields (particularly buildings) of the private and public sector. The recast of the EPBD will play a significant role in the future selection or enhancement of heating and cooling systems of a building. Especially, through the issuance of an energy performance certificate, the chances of a SC+ system to be implemented into small-scaled buildings increase a lot, considering the sustainability, the reduction of primary energy consumption and the CO_2 emissions savings achieved.

6.4 Threats

6.4.1 Technical issues

Competing technologies' capability of covering peak demand

Most of the competing technologies using fossil-fuels or electricity are controllable by the user. This means that they can be chosen in a way that they are able to cover the most extreme heating/cooling needs, operating at part load for the rest of the time. In the contrary, the SC+ systems are dimensioned to cover the average load, assuming that the periods that the demand exceeds their nominal output are negligible.

Already installed conventional systems in existing buildings (non-worthy replacement)

The payback period for replacing an already installed system by a SC+ (without subsidies), one is too long to be considered a worthy investment.

PV driven compression chillers

A significant competing technology for solar thermal systems is the photovoltaic technology that can both provide the building with electricity as well as be the driving force for a compression chiller. Moreover, less space is required for installing such a PV driven compression chiller.

6.4.2 Cost-related parameters

Volatile input material costs (e.g. copper)

An issue that can be considered as a threat for the examined technology is the respective markets for the input material. As other products, such as metals and chemicals have also fluctuating prices (for instance, copper's price is rather volatile), the manufacturing costs can be significantly affected.

6.4.3 Financial incentives

Lack of powerful incentives

In the section of opportunities, the available (financial) incentives in each participating country were mentioned. However, in some countries the incentives are limited to a mere income tax deduction or are presented as indirect incentives. They are, therefore, not strong enough to currently become driving mechanisms for the opening of the market. A significant threat for the SC+ technology is the presence of financial and other incentives for competing renewable technologies in the respective countries. Actually, most of the incentives mentioned in the section of “opportunities” refer to renewable energy technologies in general, rather than specified for solar thermal installations.

6.4.4 Market related parameters

Lack of awareness for the wider public

From the market’s point of view, a major issue is the unawareness of the wider public. Factors such as the early age of the technology, the lack of investments and publicity and, most importantly, the lack of local retailers have contributed in keeping this technology rather unknown as a significant alternative of conventional technologies.

End user’s behaviour relates with system’s performance

The system cannot be considered independently of the end user’s behavior. That is, the user’s awareness on energy efficiency, sustainability and environmental concerns play an important role on the way the system is operated and managed. An irrational use could signify also a decline of the performance whereas the frequent commitment of the auxiliary system will affect the system’s advantage regarding low operating cost.

6.4.5 Legislation

Legislation in favour of competing technologies

Similarly to the financial incentives, a number of guidelines may promote directly or indirectly the installation of competing technologies, especially in regards with renewable energy systems.

6.5 Definition of Goals

The SWOT Analysis does not provide by itself safe conclusions and means for strategic planning if it is not further analyzed. An important matter that cannot be neglected and needs to be individually addressed is the fact that all different issues (strengths, weaknesses, opportunities and threats) are weighted as equally important throughout the SWOT Analysis. For that reason, the following technique is proposed: each issue (strength, weakness, opportunity and threat) is weighted according to the likelihood of happening/being true and the severity of its impact if it does happen. Moreover, a further classification is carried out according to the time frame each issue (strength, weakness, opportunity and threat) refers to. In specific, two time frames are examined, i.e. present and future. As outcome of this analysis the following graph arises.

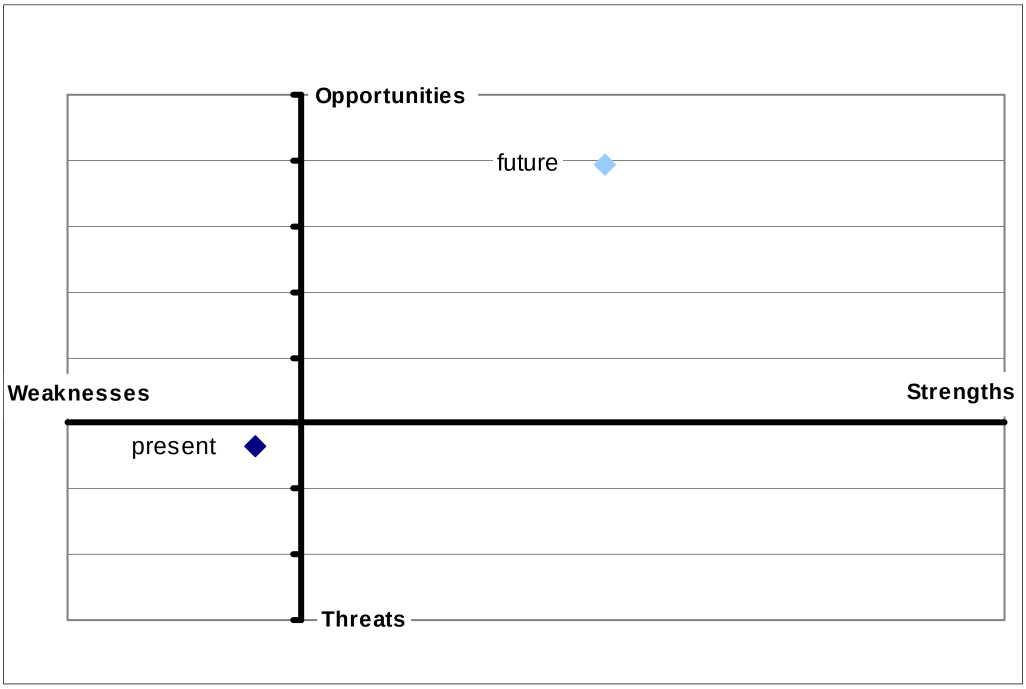


Figure 8 - Current and potential future position of SolarCombi+ systems in terms of the SWOT analysis

It is clearly illustrated that at the moment the internal consideration of the technology is rather weak. In the same way, the examination of the external factors that affect SC+ leads to a point where the SC+ systems are more threatened by the market than invited through the opening of opportunities. This suggests that, for the time being, the chances are relatively rough for their successful market establishment.

However, taking into consideration the future developments or prospects for advancements the illustrated point moves to the first quarter of the graph, being located between strengths and opportunities. This means that if the current weaknesses are minimized and the threats avoided, the future structure of the market will be much more advantageous, both internally and externally. As seen in the graph, the illustrated point is characterized both by high strengths and high opportunities. Yet a prerequisite is that certain drawbacks of the technology and market barriers are eliminated or at least minimized. For instance, the capital cost has to be significantly reduced, since it was not considered as a future weakness in this analysis, rather a current setback.

Information revealed in a SWOT analysis can be used to generate new/better strategies for the examined technology, through a significant tool called the SWOT Matrix. The SWOT Matrix is a way to formally analyze and make strengths, weaknesses, opportunities and threats a key component of the strategic planning. In specific, the strategies that constitute the SWOT Matrix are defined as follows:

	Strengths S1, S2, …	**Weaknesses W1, W2, …**
Opportunities **O1, O2, …**	**S-O Strategy**: Use Strength **S1** to take advantage of Opportunity **O1**	**W-O Strategy**: Overcome weakness **W1** by taking advantage of Opportunity **O2**
Threats **T1, T2, …**	**S-T Strategy**: Use Strength **S2** to avoid Threat **T1**	**W-T Strategy**: Minimize Weakness **W2** and avoid Threat **T2**

Figure 9 – SWOT Matrix

Derived from the aforementioned analysis based on the SWOT Matrix the following outcomes can be highlighted. As often mentioned during the analysis, the SC+ systems are quite advantageous in terms of technical characteristics, combining state of the art technology with energy efficient and environmentally friendly profile, features that with the appropriate management could be converted into powerful driving mechanisms for a complete market establishment. Moreover, both now as well as in the coming years numerous opportunities are opening in the market to welcome such technologies with the emphasis laid on energy efficiency and climate protection.

One of the most imperative issues to be handled and perhaps the most significant barrier for a more intensive market penetration is the high capital cost, which is directly connected to the absence of economies of scale. It is, actually, technical, managerial, and financial and marketing factors those that could cause the decrease of average cost as the production rises. Apparently in the case of SC+ those factors are not sufficiently developed. Effort should be, therefore, laid, on a better handling of such cost-related issues.

There are two prerequisites for achieving a considerable decrease of the costs so that SC+ systems become competitive to other technologies. The first one is attaining a high learning rate, which refers to the experience gained by manufacturing a certain technology and can be affected by technical, organizational and managerial factors. The second and most substantial one is the establishment of mass production of SC+ systems, which requires enhancement in all stages of product development and commercialization.

For this mass production to take place and for SC+ systems to become cost-competitive to other technologies, one should focus on the most distinguished strengths of the technology that are not directly related to cost parameters and promote them over competing technologies. For instance, it would be important to highlight facts as the high level of efficiency, the environmental benefits that are achieved by their operation as well as the high quality characterizing such a state of art technology.

For that reason, campaigns should be organized which would, among others, include presentations in workshops, conferences and fairs, so that a larger number of market participants becomes aware of the technology and the market interest starts being directed to its development. Moreover, official surveys should be conducted to include the customer’s satisfaction and the reliability a SC+ system can offer after having been tried, based on already existing installations. The latter should be presented as best cases, exposing the results and the gains achieved as well as the clients’ testimonials.

Currently, the indisputably most important action to be held is the mobilization of the market, politics and regulation towards the enforcing of incentives and regulatory measures that favor SC+ systems. It is therefore important for the SC+ manufacturers/distributors to approach the relevant stakeholders and decision makers, in order to promote the establishment of financial or other incentives that could significantly reduce initial investments and at the same time intercede to the formulation of guidelines and regulations. Important would also be the approach of public authorities and possibly the initiation of pilot SC+ projects that would gain much attention and popularity.

In addition, the extension of the network of local retailers would, among numerous benefits, sufficiently reduce certain cost factors, such as transportation, installation and maintenance cost. All of the aforementioned processes currently require further expenses, since SC+ retailers and adequately trained personnel (engineers, installers, etc) are often absent even in nation-wide level. An important step would, therefore, be contacting and partnership with local retailers, or even opening of new companies to create a strong and reliable network of local retailers. Moreover, training courses addressed to engineers and installers should be organized at a local level, expanding the market in terms of expertise and services. These developments would not only make SC+ systems known to the wider public by exploiting the opportunity of applying a mature and professional strategy for dissemination and publicity, but also provide improved services and reliability.

It should be, however, considered that a possible opening of the market, in terms of retailers' network expansion, promotion and advertising has to be preceded by the establishment of certain market conditions. That is, the systems will have to be technologically mature, tested and reliable, services will have to be developed to provide the necessary support and maintenance and adequate financial or other incentives will have to be issued to support the initial investment of the end customers. Otherwise, a rapid expansion of the market, linked to the opening of new businesses and co operations will probably fail.

As a future tendency it should be considered that the promotion of SC+ systems should be targeted to the most promising regions and applications as resulted through the respective analyses conducted in the framework of the project. According to that, effort should be given to focus on new buildings. According to the conducted economic analysis, it was proved more cost effective to install SC+ systems to new buildings than replace equipment in existing buildings. Furthermore, the design and architectural prospects for building integration may help substantially the avoidance of possible barriers concerning surface/space availability or aesthetics. Besides, the current regulatory and subsequently technology and market trends concerning the energy efficiency of buildings move to a more sustainable consideration of the new buildings.

7 Description and Visual Representation of Most Promising Markets

The physical location of the system installed fixes the amount of solar energy provided and to some extent the domestic hot water, heating and cooling needs. The combination of useful energy possibly harvested and overall loads determines the most promising climates for the installation of a solar combi plus application.

7.1 Building Indexes and Demands

The psychrometric diagram of Figure 10 delimitates into trapezoids the acceptable living conditions for winter and summer season. As can be seen, a humidity of 50%, temperatures of 21ºC in the heating season (blue trapezoid), and 25ºC in the cooling one (pink) assure the inside quality. Moving the red point to the left on the 50% relative humidity curve, the amount of energy that the building losses in winter time to the environment is lower. The contrary happens in summer time with the blue point. To define parameters proportional to the building loads, it was decided to evaluate as internal conditions, 21°C in winter time, and 26°C in the summer season (see Figure 11).

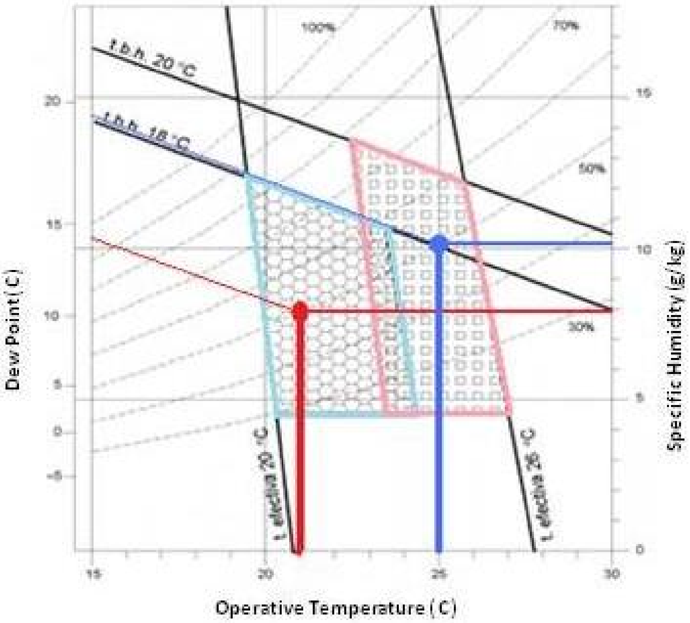


Figure 10 – Optimal comfort conditions on a psychrometric diagram.

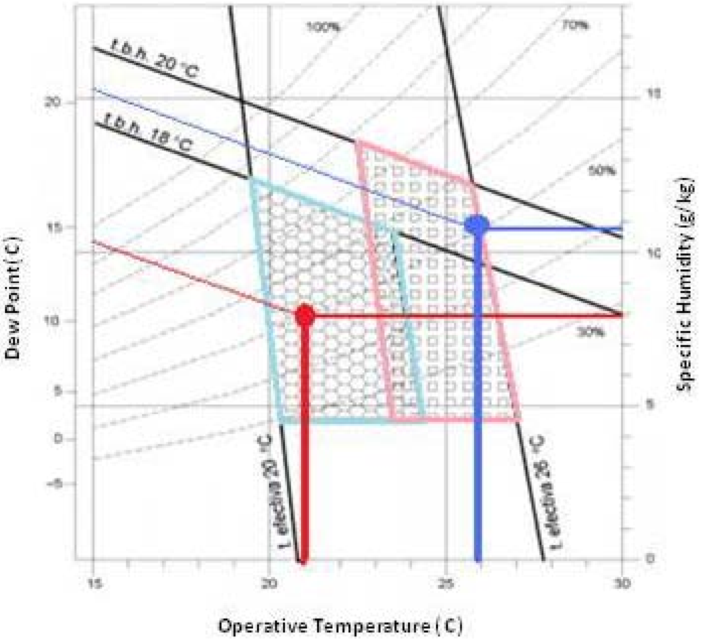


Figure 11 – Ambient conditions selected within the Solar Combi+ project.

The following two parameters (Heating Degree Days and Cooling Degree Days) serve as a first evaluation of the energy demand of a building, based only on the external temperatures. Both parameters compare the external temperatures with the in-house ones that always assure conditions perfectly acceptable inside the building all along the year (calculated for a relative humidity of 50%). While the winter parameter (HDD) is a good figure of the heating needs of the building, the summer factor (CDD) is a doubtful one, because it does not take into account humidity (latent heat) and the solar gains, that in some cases are the highest contributions. Nevertheless it can be used in an easy way, as a first approximation.

7.1.1 HDD (Heating Degree Days)

This parameter is a quantitative index designed to reflect the energy demand needed to heat a building. It is derived from daily temperature observations and calculated as the yearly sum of the difference in degrees between a base temperature that defines the internal building ambient temperature (typically 21ºC is the temperature where the loses with the environment do not exist) and the external dry temperature .

$$HDD = \sum_{h=1}^{8760} \frac{\left(21 - T_{amb,h}\right)}{24} \approx \sum_{d=1}^{365} \left(21 - T_{amb,d}\right)$$

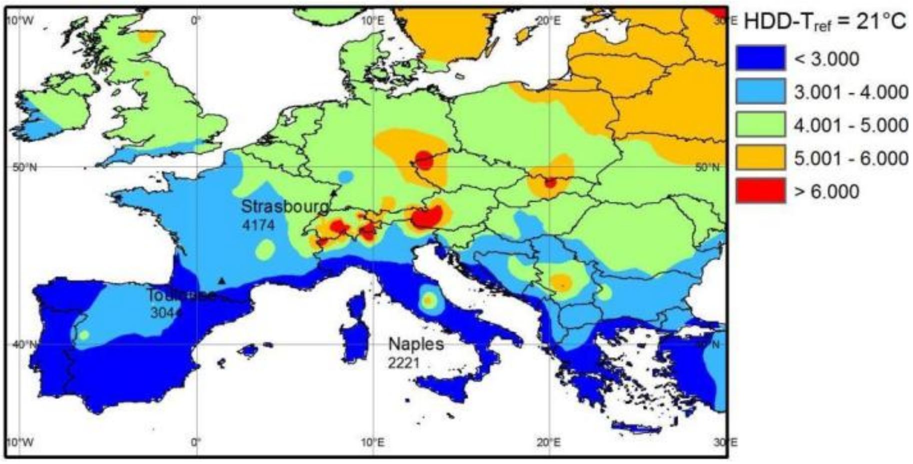


Figure 12 - Heating degree days in Europe

In the case of SC+, it can be seen how for a division of Europe in 5 zones, the studied cities belong to the three hottest ones. (Naples 2221, Toulouse 3040, Strasbourg 4174). The other two zones that correspond to HDD values over 5000 are not going to be studied, overall because as can be seen in the following figures, there will not be enough needed of cooling to be a case of interest for SC+ systems.

The comparison of the three cities shows a increment of CDD of 36% between Naples and Toulouse and 88% between Naples and Strasbourg.

7.1.2 CDD (Cooling Degree Days)

The Cooling Degree Days parameter (CDD) is defined in a similar way to evaluate the gains obtained by the building due to the external temperatures (reference temperature taken is 26ºC).

$$CDD = \sum_{h=1}^{8760} \frac{(T_{amb,h} - 26)}{24} \approx \sum_{d=1}^{365} (T_{amb,d} - 26)$$

Again, as it can be seen in the figure 4, the correspondent values for CDD are highly different for the chosen cities. (70 for Naples, 26 for Toulouse and 9 for Strasbourg). Comparing to the value of Naples, Toulouse and Strasbourg are respectively 63% 87% lower.

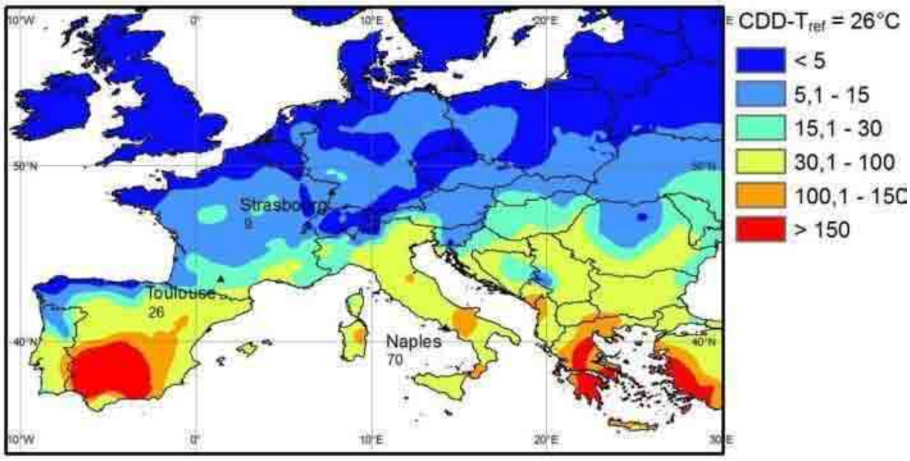


Figure 13 - Cooling degree days in Europe

7.1.3 Cooling and Heating Demands delivered by the Simulation of the building.

The total demands of cooling and heating of the buildings simulated into the SC+ program are shown in Table 1.

Table 1 - Building demands simulated [kWh/m^2/year]

kWh/m^2/y	Office		Typical House			Low consumption House		
	Heating	Cooling	Heating	Cooling	DHW	Heating	Cooling	DHW
Strasbourg	69.74	34.19						
Toulouse	34.13	50.28	46.05	5.69	12.66	24.58	6.12	12.66
Naples	9.22	80.75	21.11	18.45	11.43	9.37	17.45	11.43

Comparing Toulouse with Naples, it can be seen that the heating loads range between about 9 and 46 kWh/m^2/year. Cooling loads range between 6 an 20 kWh/m^2/year when residential buildings are regards, while much higher values are seen with regards to the office application (50-80 kWh/m^2/year).

If Naples is compared to Strasbourg (only the office application was simulated in this case), the heating loads are 7 times higher in Strasbourg, while the cooling loads are only three times higher in Naples.

7.2 Radiation parameters

The total radiation on a horizontal surface was calculated first from the direct normal and diffuse radiation of the meteorological files.

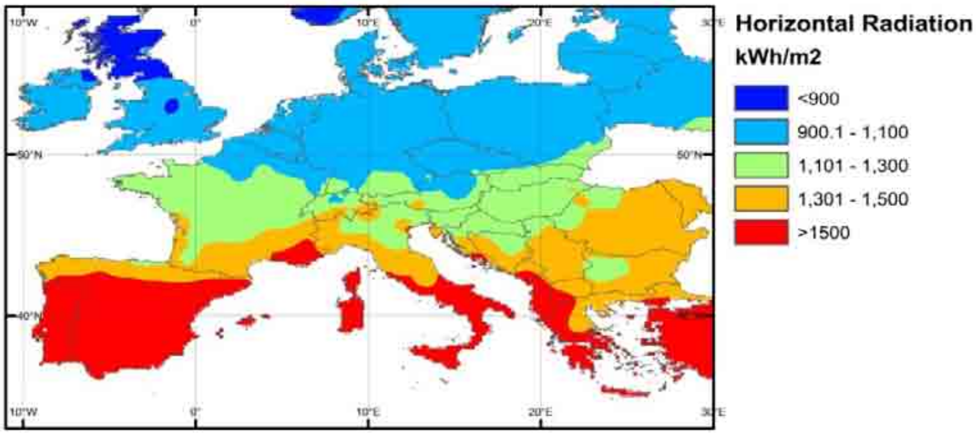


Figure 14 - Total radiation on horizontal

A delimitation of these data was needed to evaluate the suitable energy on a tilted surface oriented to the south. For comparison purposes, the tilt angle of the collectors chosen for all European countries was 40º, even though the best value varies with the latitude. Moreover, two different maps were created, one for the heating season and one for the cooling season (cooling season from 15th May to 15th September, heating season is the remaining part of the year).

The last two figures represent the maximum amount of energy that can be collected from the sun, independently of the type of collector and the temperature needed in the processes, so these graphs correspond to the upper limits in terms of possible energy collected. It is interesting to notice in table 2 that the total energy that can be captured in the eight months of heating and in the four months of cooling season is nearly identical for the three cities.

To produce more representative figures, two more parameters were introduced to take into consideration ambient temperature and collector’s outlet temperatures: Critical and Useful Radiation.

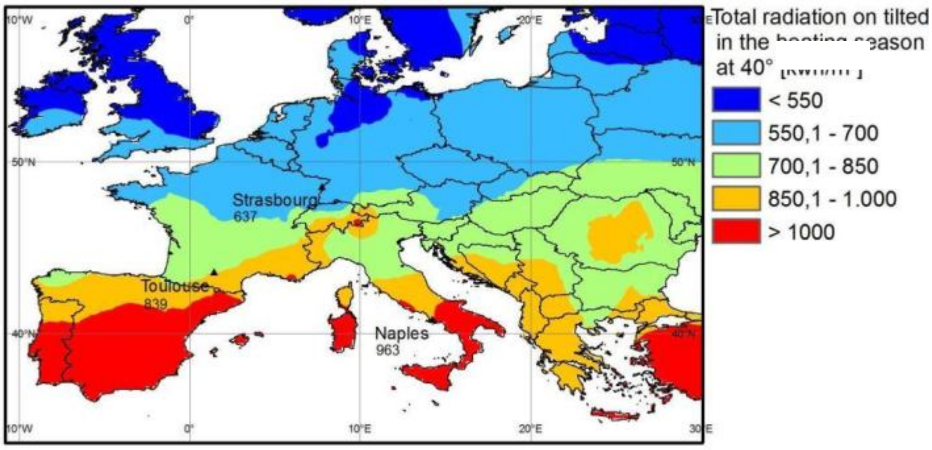


Figure 15 - Total radiation on tilted surface in the heating season (8 months).

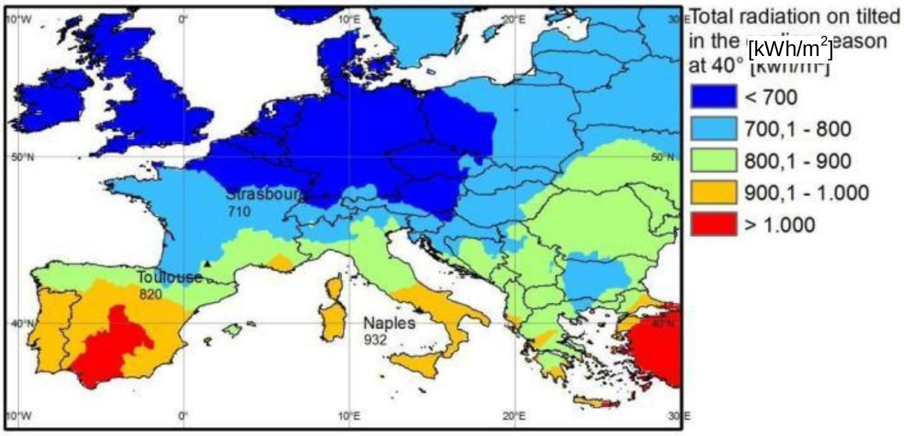


Figure 16 - Total radiation on tilted surface in the cooling season (4 months).

Table 2-Radiations on horizontal, Tilted angle 40º for Heating and Cooling Season

	Total Radiation Horizontal	Heating Season Radiation Tilted 40º, Faced South (8 months)	Cooling Season Radiation Tilted 40º, Faced South (4 months)
Strasbourg	1540	637	710
Toulouse	1897	839	820
Naples	2135	963	932

7.2.1 Critical radiation

A thermal collector is defined by its efficiency, that evaluates its performance as the ability of solar radiation harvested minus the thermal losses to the environment:

$$\eta = IAM \times k_0 \ - k_1 * \frac{\left(T_{avg} - T_{amb}\right)}{G_{\perp}} - k_2 \frac{\left(T_{avg} - T_{amb}\right)^2}{G_{\perp}}$$

- k_0 = optical efficiency angle (0.823 - flat plate, 0.601 – evacuated tubes, with respect to gross collectors' area)
- k_1 =linear loss coefficient (3.02 $W/(m^2*K)$ - flat plate, 0.767 $W/(m^2*K)$ – evacuated tubes, with respect to gross collectors' area)
- k_2 = quadratic loss coefficient (not used in this case, due to its secondary effects at temperatures up to 100 °C)
- T_{avg} = average temperature
- T_{amb} = ambient temperature
- IAM = Incident Angle Modifier, evaluates in percentages the amount of energy that arrives to the collector depending on the two angles (transversal and longitudinal) that the sun forms hourly with the tilted collector. $IAM = IAM_T \times IAM_L$

The Critical Radiation is defined as the level of radiation that creates the equilibrium between the losses from a collector and the energy harvested for a predetermined temperature. Developing the later equation for an efficiency equal to 0 and without taking into account the quadratic loss coefficient, the irradiation obtained is represented by:

$$I_{Critical}^{temp,coll} = \frac{k_1}{IAM \times k_0} * \left(T_{procces} - T_{amb}\right)$$

As can be seen, to define the Critical Radiation it should be previously defined: the type of collector, the IAM angles (longitudinal and transversal) and the temperatures needed for the considered processes (temperature at the outlet of the collectors in a first attempt).

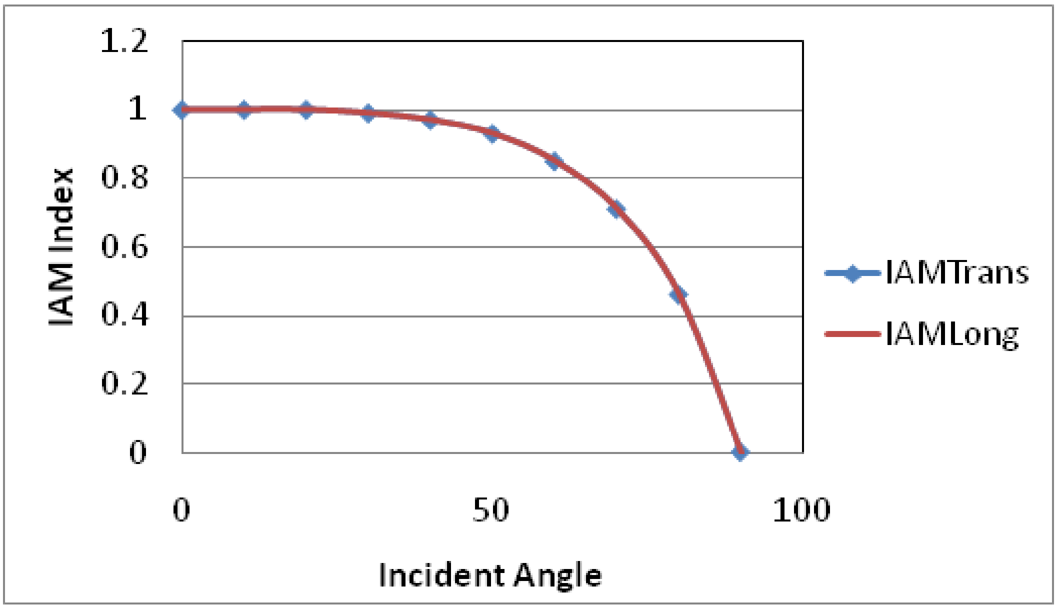


Figure 17 - Flat plate collector: $k_0= 0.823$, $k_1= 3.02\ W/m^2K$

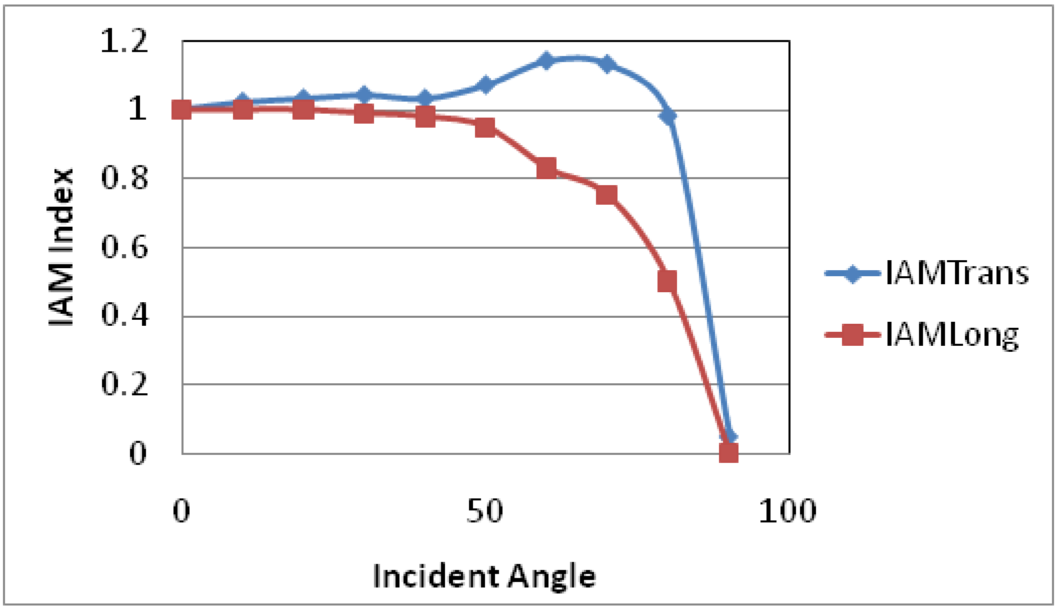


Figure 18 - Evacuated tube collector: $k_0= 0.601$, $k_1= 0.767\ W/m^2K$

7.2.2 Useful radiation

It is defined as the difference between Total Radiation received by a collector and its Critical Radiation. It represents the maximum, ideal amount of energy for a given collector and climate conditions (radiation and ambient temperature) that can be used to warm the thermal fluid up to a given temperature:

$$I_{Useful}^{temp,coll} = I_{total} - I_{Critical}^{temp,coll}$$

Within this project, the process temperatures considered were dependent on the technologies of the sorption chillers used for the cold water production, on the needs to distribute domestic hot water and heating. Therefore, the temperatures considered for the computation of the Critical Radiation were:

- 40ºC for heating through direct feeding of radiant floors or fan coils.
- 60ºC for DHW all along the year.
- 70ºC for Adsorption chillers (summer time).
- 90ºC for Absorption chillers (summer time).

It should be remembered that the results are related to the maximum amount of harvested energy, at certain process and ambient temperatures; therefore, in the case of the chillers, the temperature evaluated is the minimum one that can drive the system. Moreover, the characteristic parameters of the collectors (k_0 and k_1) are taken constant for the calculations, which is only achievable if their inlet temperature is also retained constant. This is only possible if the demand and the useful radiation always overlap, which is not the case. As a result, the model used introduces some simplifications that result in somehow overestimated figures, when compared with actual energies available for heating, cooling and domestic hot water production. Nevertheless the model is well suited for the purpose of the most promising markets analysis, since it allows an easy comparison of the European regions in terms of offered solar energy at different year times.

7.3 Solar Thermal Collectors Market

Figure 19 shows the European solar thermal market in terms of collectors' area sold up to the entire 2008. As it can be seen, the far largest market is Germany with about 11 Mm^2 installed; Greece, Austria, Italy, France and Spain follow with about 3.9, 3.2, 1.6, 1.6 and 1.4 Mm^2 sold. If the collectors' area per inhabitant is regarded, Austria, Greece and Germany again have the largest figures (388, 344 and 135 m^2/1000 inhabitants respectively).

Therefore, if the status quo is regarded, the last three countries seem to offer the best possibilities for the entry of the solar heating and cooling technologies on the market. Other countries like Cyprus and Malta present noteworthy values of collectors' area per inhabitant (873 and 75 m^2/1000 inhabitants respectively); however, they cannot be regarded as promising markets, as a whole, due to their limited absolute size. The other countries cited (Italy, Spain and France) follow by far.

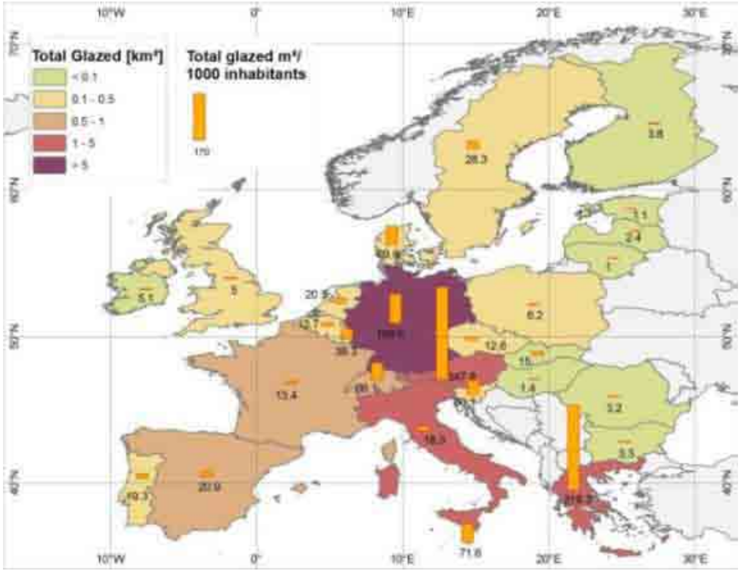


Figure 19 – Solar thermal market in Europe. Cumulative installed solar thermal fields at 2008.

If a "growth" approach is used to identify promising markets, the collectors installations of the last four years can be considered. The market increase in this time range shows clearly that also other countries can be taken into account; among the southern ones with a good potential of solar energy exploitation, Slovenia, Portugal, and again France, Spain and Italy show surprising rises of their solar thermal markets: +789%, +760%, +646%, +382% and +260% respectively (see Figure 20, Figure 21). The three greatest markets (Germany, Austria and Greece) grow at slower rates, although still +34% is observed in Greece, +90% in Austria and +180% in Germany.

Therefore, all mentioned countries can be considered somehow suitable ones for solar thermal applications and promising for solar combi plus installations.

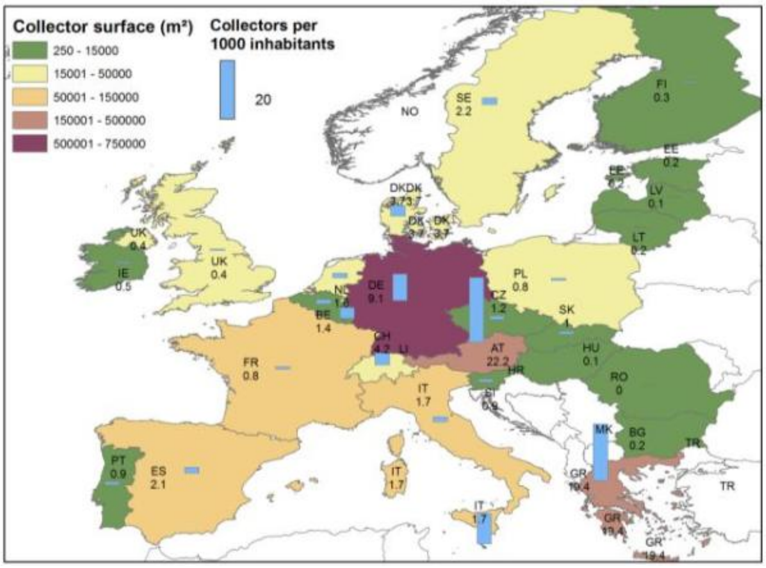


Figure 20 – Solar thermal market in Europe. Installations in 2004

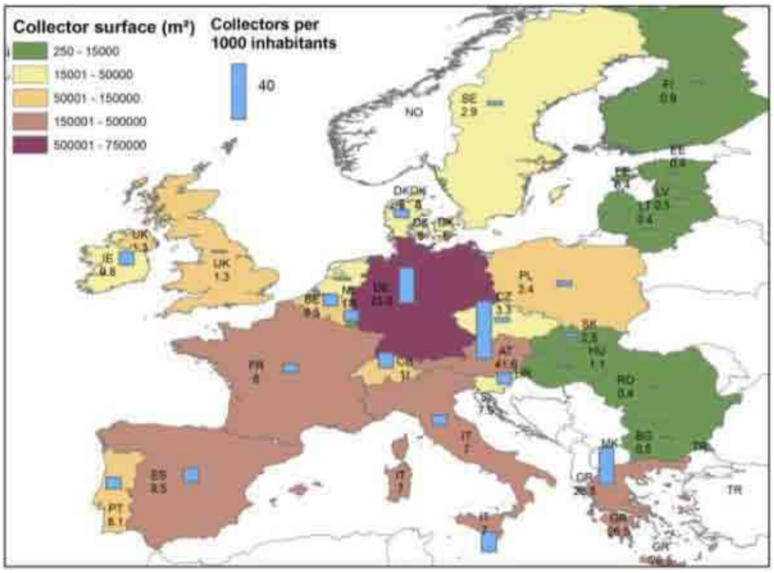


Figure 21 – Solar thermal market in Europe. Installations in 2008

Table 3 – Solar thermal collectors installations in Europe – Source ESTIF, AEE-Intec

	m^2				m^2/1000 inhabitants				
	2004	2006	2008	Cumulat at 2008	2004	2006	2008	Cumulat at 2008	Increase 04-08
AT	182594	292669	347703	3240330	22.2	35.3	41.6	387.8	187%
BE	14700	35636	91000	268947	1.4	3.4	8.5	25.0	607%
BG	1800	2200	4000	31600	0.2	0.3	0.5	4.2	250%
CH	31160	51863	85000	593980	4.2	6.9	11.0	77.1	261%
CY	30000	60000	68000	693200	40.0	77.1	85.6	873.1	214%
CZ	12250	22030	35000	165100	1.2	2.1	3.3	15.8	275%
DE	750000	1500000	2100000	11094000	9.1	18.2	25.6	135.3	281%
DK	20000	25300	33000	418280	3.7	4.6	6.0	75.9	162%
EE	250	300	500	1970	0.2	0.2	0.4	1.5	200%
ES	90000	175000	434000	1411166	2.1	3.9	9.5	30.8	452%
FI	1630	3200	4800	25293	0.3	0.6	0.9	4.7	300%
FR	52000	220000	388000	1624100	0.8	3.5	6.0	25.2	750%
GR	215000	240000	298000	3868200	19.4	21.5	26.5	343.6	136%
HU	1500	1000	11000	25250	0.1	0.1	1.1	2.5	1100%
IE	2000	5000	43610	74400	0.5	1.2	9.8	16.7	1960%
IT	97738	186000	421000	1606230	1.7	3.1	7.0	26.7	411%
LT	500	600	840	4290	0.2	0.3	0.4	1.9	200%
LU	1700	2500	3600	22500	3.7	5.3	7.3	45.6	197%
LV	500	1200	1800	7150	0.1	0.4	0.5	2.1	500%
MT	4215	4500	6000	35360	10.5	11.0	14.5	85.5	138%
NL	26300	14685	25000	363341	1.6	0.9	1.5	22.0	93%
PL	28900	41400	129632	365676	0.8	1.1	3.4	9.6	425%
PT	10000	20000	86000	318950	0.9	1.9	8.1	30.0	900%
RO	400	400	8000	94300	0.0	0.0	0.4	4.4	n.a.
SE	20058	28539	26813	289207	2.2	3.1	2.9	31.2	131%
SI	1800	6900	16000	137300	0.9	3.4	7.9	67.6	877%
SK	5500	8500	13500	95250	1.0	1.6	2.5	17.6	250%
UK	25000	54000	81000	385920	0.4	0.9	1.3	6.3	325%

7.4 Energy prices

Figure 22 and Figure 23 report the gas and electricity prices in Europe. Customers are most sensitive to their energy consumption, and therefore might be more sensitive to energy efficiency, in countries where large values are encountered for both prices. From the maps, those (southern) countries are namely Germany, Austria, Portugal, Czech Republic, Slovakia, Spain, Italy and France.

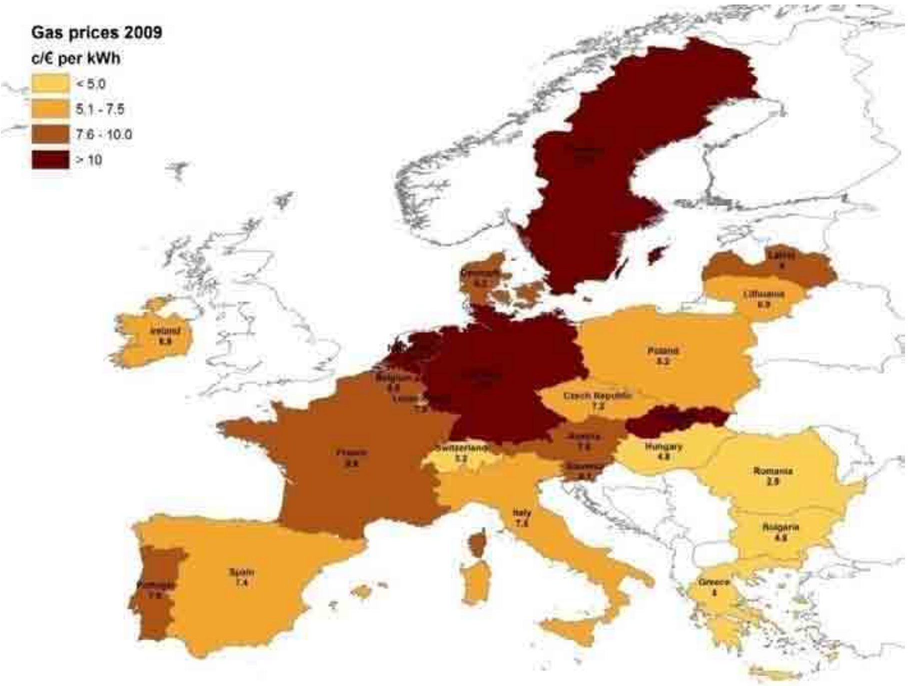


Figure 22 – Gas prices in Europe – Source Eurostat

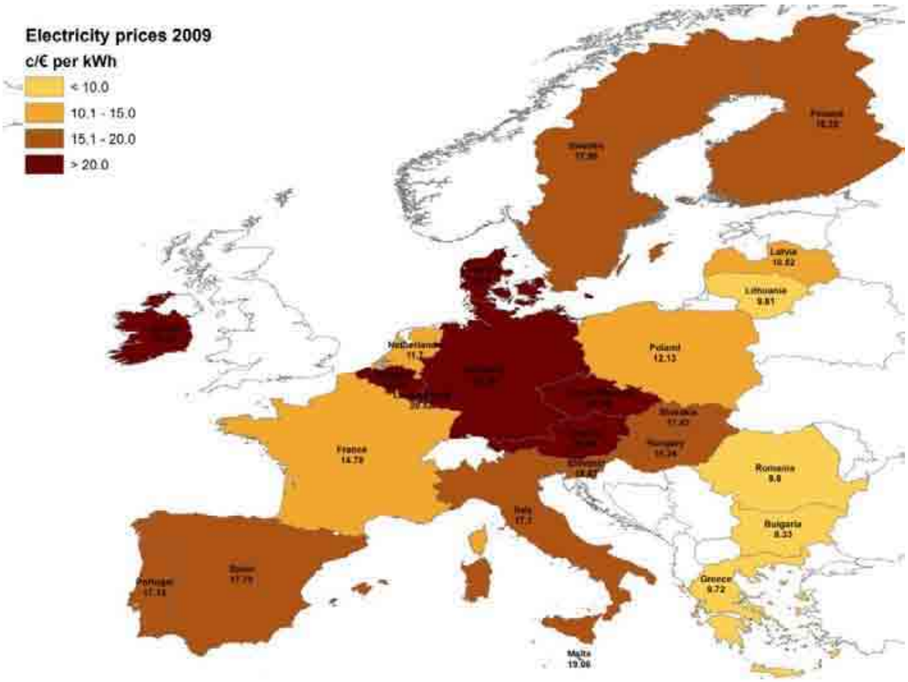


Figure 23 – Electricity prices in Europe – Source Eurostat

7.5 Heating and Cooling Loads

In the HDD map presented (Figure 12), it can be seen how much the HDD changes within Europe: the figure increases (the energy demand for heating rises proportionally) from about 2000°HDD in south Europe to more than 5000°HDD in the northern countries (compare also the data relative to the three cities studied within the project, Table 4). Comparing the latter map with the one in Figure 13 (CDD), it can be seen that the range of values is much narrower; this is due to the fact that only four months are taken instead of eight and to the lower average temperature differences between the inner and the outer temperatures that are reached in summer. Moreover, the latent and radiative loads are not considered in CDD definition. In any case, the cooling loads are about one order of magnitude lower than the heating loads in the worst cooling case (Naples). Nevertheless, the values might easily vary of a factor 8 moving from south to north Europe (Table 4).

Table 4 - HDD and CDD values for the cities studied in the project.

	HDD (21°C)	CDD (26°C)
Strasbourg	4174	9
Toulouse	3044	26
Naples	2221	70

On the base of these last numbers, Naples and Toulouse will fit better to solar combi plus systems due to high both heating and cooling demands, while Strasbourg’s loads will point mainly on heating requirements.

7.6 Space Heating Useful Radiation (40ºC)

Looking at the useful energy at the collector outlet, the lowest process temperatures -useful for heating purposes through radiant floors- are analyzed first. It can be seen that, when fluid temperatures of 40°C are considered during the heating period, considerable amounts of energy can be elaborated both in southern and northern regions (see Table 5, Figure 24 and Figure 25). When looking at Figure 24 and Figure 25, relating to flat plate and evacuated tube collectors respectively, values range between about 300 kWh/m^2/year and 900 kWh/m^2/year. If the three cities are considered, the values of useful radiation change between 400 and 700 kWh/m^2/year in the case of flat plate collectors and 540 and 860 kWh/m^2/year in the case of evacuated tube ones.

Table 5 –Useful radiation [kWh/m²/year] at 40°C for heating (8 months)

	FP-Heating Season	ET-Heating Season	Relation FP/ET
Strasbourg	397	537	73.92%
Toulouse	568	735	77.28%
Naples	690	861	80.13%

The useful radiation for the evacuated tube collectors in Strasbourg is approaching the one for the flat plate collectors in Toulouse and the useful radiation in Toulouse exceeds the one in Naples. The effectiveness of the evacuated tubes is more significant in the northern countries: the relation between energy obtained by flat plate and evacuated tube is presented in the last column of Table 5 that shows values between 74 and 80%. Therefore, to cover an acceptable part of the demand in northern countries, the most efficient technology could be needed. However, the choice is left also to space availability and economical aspects.

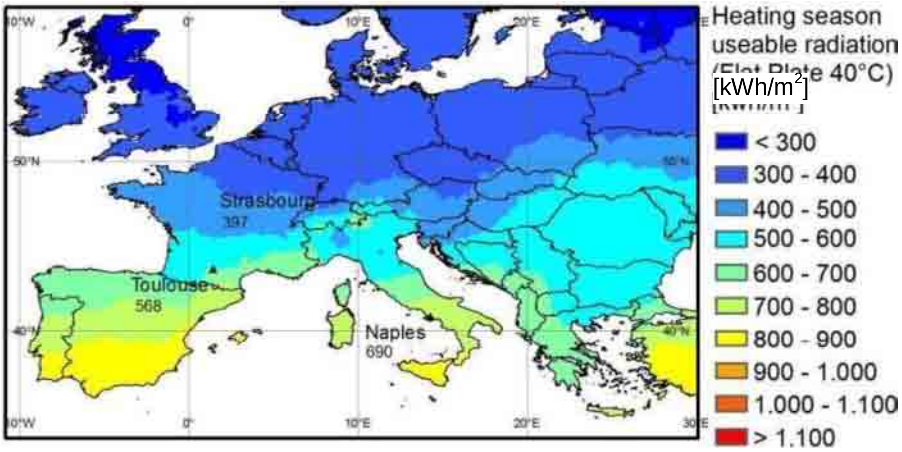


Figure 24 - Heating season (8 months) useable radiation for flat plate collectors at 40°C

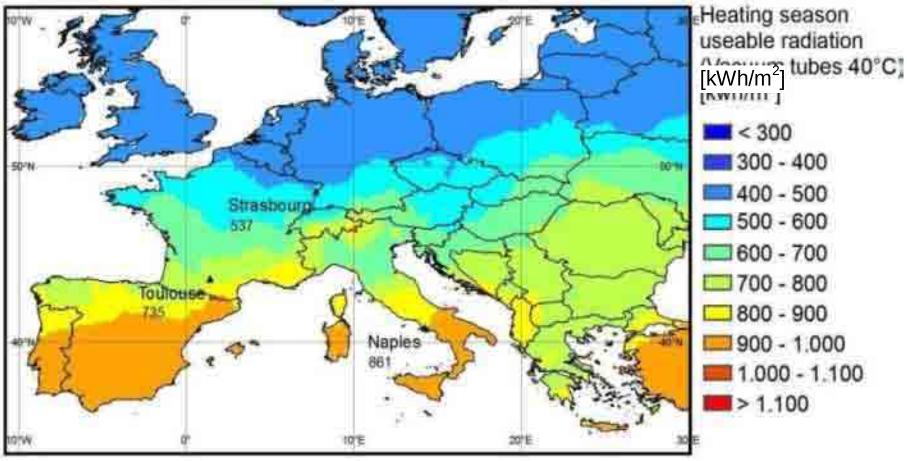


Figure 25 - Heating season (8 months) useable radiation for evacuated tube collectors at 40°C

7.7 DHW Preparation Useful Radiation (60ºC)

Comparable amounts of energy can be obtained during the summer season and the remaining part of the year (again, it must be remembered that summer season is half time the winter one.), if 60°C hot water is regarded. In Figure 26 and Figure 27 (Heating season), values range again between about 300 kWh/m^2/year and 900 kWh/m^2/year. If the three cities are considered, the values of useful radiation change between 300 and 550 kWh/m^2/year in the case of flat plate collectors and 500 and 800 kWh/m^2/year in the case of evacuated tube ones. During the cooling season (Figure 28 and Figure 29), the useful radiation reaches for the three cities values between 450 and 650 kWh/m^2/year in the case of flat plate collectors and 600 and 850 kWh/m^2/year in the case of evacuated tube. Remarkable good results are seen in the top right corners of the maps; however, this is due to the low amount of data recorded in those places that produces interpolation mismatches. Due to the higher temperatures needed when Domestic Hot Water preparation is considered, evacuated tubes increase the advantages seen in the previous chapter to an averaged 28% for the cooling season and 36% in winter time (see Table 6 and Table 7). Those differences can be explained by the relations between radiation and external temperatures, responsible for the thermal losses. More severe temperature differences are encountered on average in winter time, between solar collector and the surrounding environment.

Table 6 –Useful radiation [kWh/m^2/year] at 60°C for domestic hot water preparation

	FP-Cooling Season	ET-Cooling Season	FP-Heating Season	ET-Heating Season
Strasbourg	438	624	302	490
Toulouse	530	734	445	678
Naples	632	855	552	802

Also it can be calculated the relation among the three cities for a determined DHW demand (tap temperatures differ of some degrees along the year for the cities, but the total demand of energy to heat DHW is under the energy differences obtained for the three locations). From the point of view of DHW, the most promising market corresponds to Naples, due to the 20% bigger results compared with Toulouse and approximately 50% with Strasbourg. The election between flat plate and evacuated tube collectors depends again on the prices of the collectors for a given demand.

Table 7 - Relation between energies harvested by FP and ET in a determined season

	Relation FP/ET Cooling Season	Relation FP/ET Heating season
Strasbourg	70.20%	61.63%
Toulouse	72.21%	65.63%
Naples	73.91%	68.82%

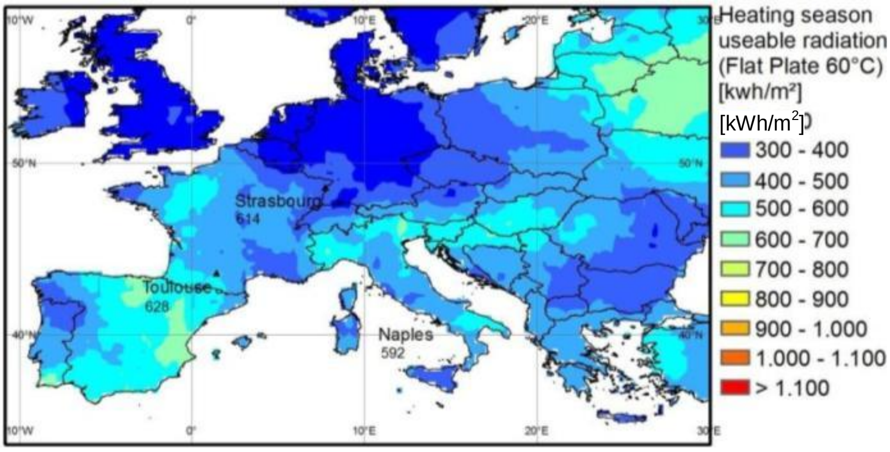


Figure 26 - Heating season (8 months) useable radiation for flat plate collectors at 60°C

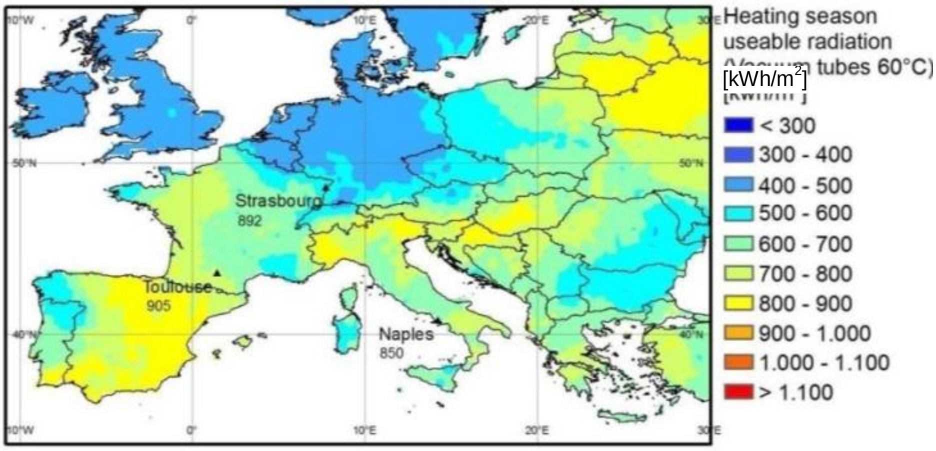


Figure 27 - Heating season (8 months) useable radiation. Evacuated tube collectors 60ºC

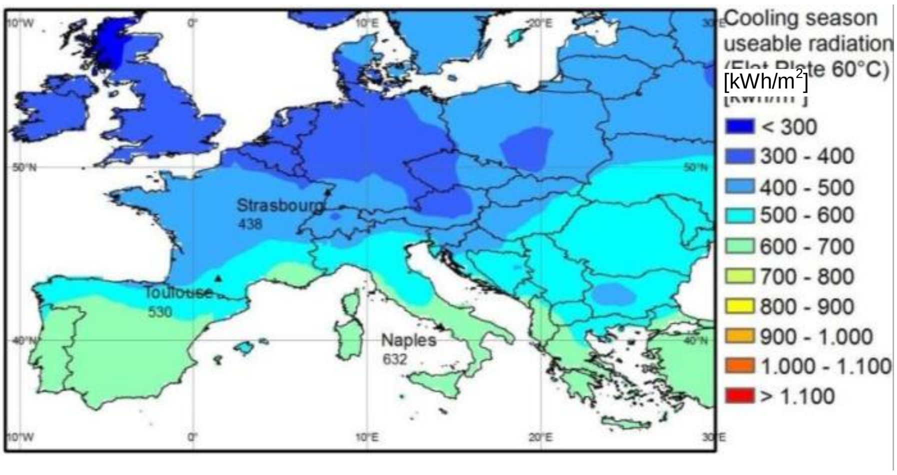


Figure 28 - Cooling season (4 months) useable radiation for flat plate collectors at 60°C

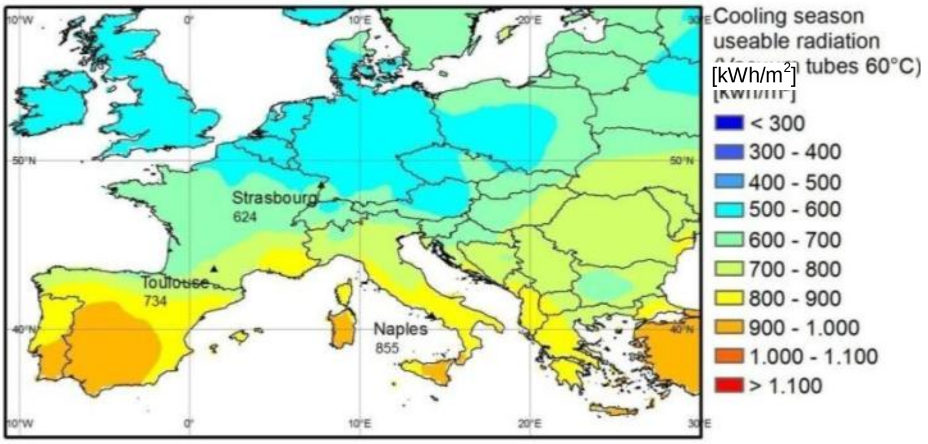


Figure 29 - Cooling season (4 months) useable radiation for evacuated tube collectors at 60°C

7.8 Sorption chillers driving Useful Radiation

In order to define the most promising markets, the definition of the demand for the building is needed: the decrease of available radiation in the northern countries could be counterbalanced by an equivalent, or even higher, drop on the cooling demand. As seen in Table 1, the cooling demands for Strasbourg and Toulouse are 60% and 40% lower than the one of Naples (Office Building case). For the domestic applications cases, 70% and 65% lower energy demanded in Toulouse is obtained if compared with Naples.

7.8.1 Adsorption chillers (70ºC - Cooling season)

If the available energy is regarded at a temperature useful for driving adsorption chillers (70°C), In Figure 30 and Figure 31, values range again between about 300 kWh/m^2/year and 850 kWh/m^2/year. If the three cities are considered, the values of useful radiation change between 400 and 600 kWh/m^2/year in the case of flat plate collectors and 600 and 850 kWh/m^2/year in the case of evacuated tube.

Taking Naples again as the reference location, the reduction of the useful radiation is in the order of 18% and 33% in Toulouse and Strasbourg respectively when flat plate collectors are taken, and in the order of 15% and 28% in Toulouse and Strasbourg respectively when evacuated tube are considered.

From this analysis it comes out that an easier cooling coverage (for given building and collectors area) can be provided in the northern countries. However, it has to be considered that as far as the cooling demand drops, the economics of the investment for cooling increases up to inacceptable values. Passive cooling can be contemplated when very low cooling loads are encountered. Comparing Table 7 (Cooling season) with Table 8 it turns out clearly also that the energy harvesting effectiveness of evacuated tube collectors becomes more and more significant as far as the needed temperature levels rise.

Table 8 –Useful radiation [kWh/m^2/year] for cooling (4 months)

	FP-70°C	ET-70°C	Relation FP/ET 70ºC
Strasbourg	390	604	64.57%
Toulouse	478	714	66.95%
Naples	577	834	69.18%

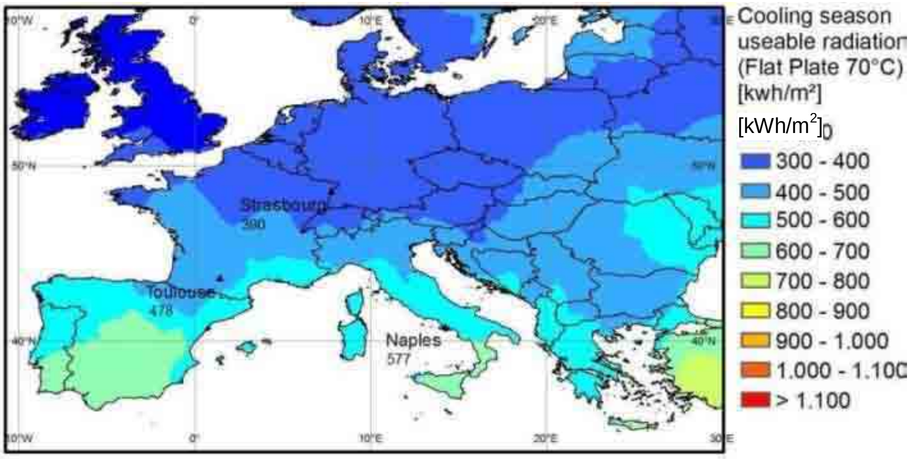


Figure 30 - Cooling season (4 months) useable radiation for flat plate collectors at 70°C

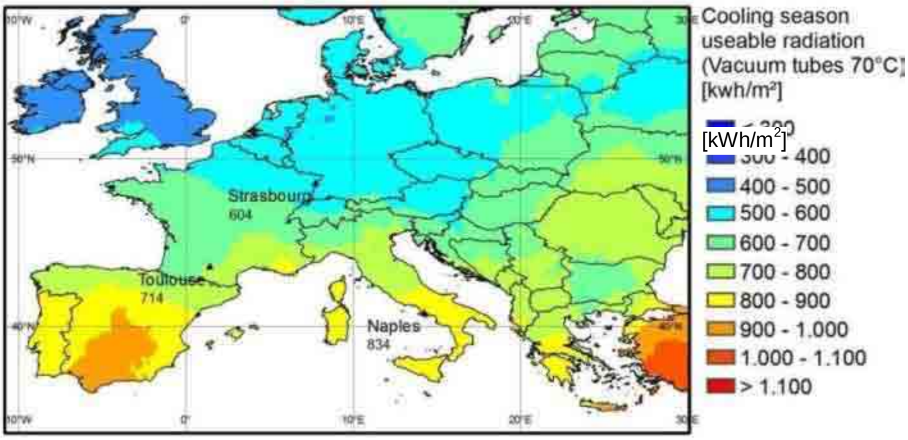


Figure 31 - Cooling season (4 months) useable radiation for evacuated tube collectors at 70°C

7.8.2 Absorption chillers (90ºC - Cooling season)

The comments made in the previous paragraph hold for the useful energy available at a 90°C temperature level. In Figure 32 and Figure 33, values range again between about 300 kWh/m^2/year and 800 kWh/m^2/year. The values of useful radiation for the three cities change between 300 and 500 kWh/m^2/year in the case of flat plate collectors and 550 and 800 kWh/m^2/year in the case of evacuated tube.

Comparing Table 7 (Cooling season) with Table 8 and Table 9 it is noticed once again that the energy harvesting effectiveness of evacuated tube is much more relevant than the one of the flat plate collectors as far as the temperatures needed increase and the location of the system moves to the north. As much as twice effectiveness is obtained with evacuated tube collectors when high temperatures are regarded.

The useful radiation reduction from Naples to Toulouse and to Strasbourg is comparable with the one shown in the previous paragraph: 20% and 36% in Toulouse and Strasbourg respectively when flat plate collectors are taken, and 16% and 29% when evacuated tube are considered.

Table 9 –Useful radiation [kWh/m^2/year] for cooling (4 months)

	FP-90°C	ET-90°C	Relation FP/ET 90ºC
Strasbourg	306	565	54.16%
Toulouse	383	674	56.82%
Naples	474	793	59.77%

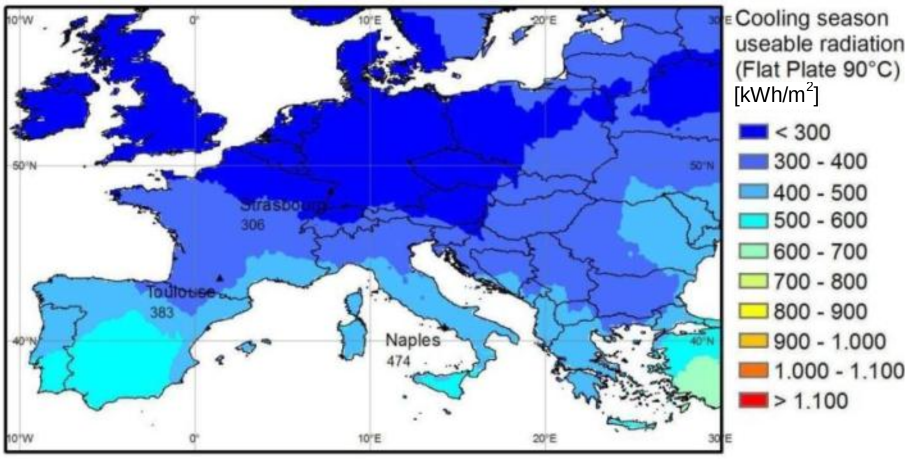


Figure 32 - Cooling season (4months) useable radiation for flat plate collectors at 90°C

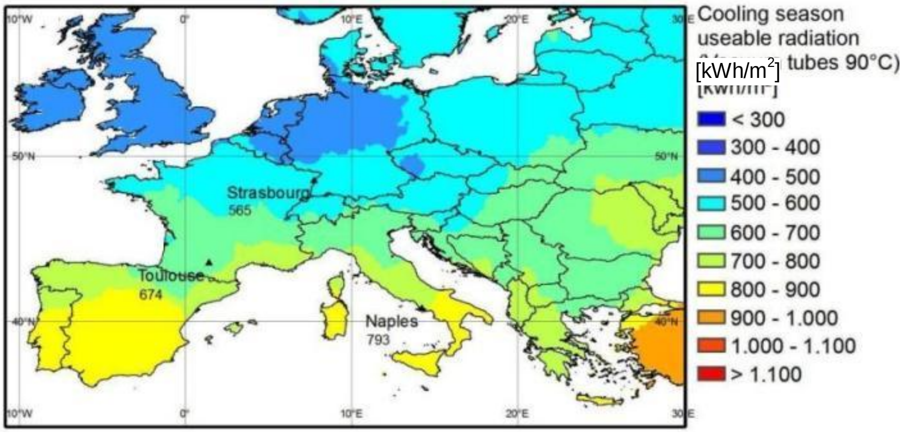


Figure 33 Cooling season (4 months) useable radiation for evacuated tube collectors at 90°C

7.9 Conclusions

All the investigated locations are suitable under the point of view of the heating needs and potential coverage of the loads through a high fraction of solar energy, due to the low temperatures needed (40°C were considered as heating temperature level). Southern countries are obviously more suitable for cooling applications due to the significantly higher radiation, which is available, while passive cooling could be a more adequate solution to cover northern countries requirements. However, cooling needs might result much higher too in southern regions, both during the days and the nights.

The technologies used for cooling (ab-/adsorption chillers) and for harvesting the solar energy have to be considered too: as far as the needed temperature levels go higher and the location moves northern, more effective solar collectors shall be adopted. The extra saving obtained with evacuated tube collectors should always be compared with the extra initial system costs. The seasonal demands are also important, i.e. cooling demands can be proportionally lower than the winter ones and the energy increase due to more expensive collectors not very significant.

Therefore, although the return of the investment is cut when combined high heating, cooling and DHW loads are encountered, a “most promising market” cannot be stated within the ones analyzed, since the selection of a good location is so much dependent on the technology employed (both for heating and cooling and for the construction of the buildings). The technology and the economics of the specific application have to be evaluated.

8 Identification of Standard System Configurations

The standard configurations analysis shows that the sizing of a solar combi+ system independently of the chiller technology can be obtained: sizes of 5 m^2/kW_{ref} and 75 l/m^2 provide best loads' coverage under all considered conditions. Due to heating requirements, larger collectors areas could be more suitable in residential applications; however, the additional gain, paid through a larger and expensive system, would be negligible. The best working technologies are in any considered case chilled ceiling as a distribution system, evacuated tubes collectors and wet cooling tower. Sizing of the components with an integrated process is also of utmost importance. Even though standard components' sizing can be individuated, a large variability of the results was detected as a consequence of the location, application technologies and chiller employed.

8.1 Best Configurations

The first step of the analysis was the choice of suitable configurations through optimization functions that account for energetic and environmental performance of the system. The following two parameters were taken into consideration:

- total solar fraction
- total electrical efficiency
- yearly relative primary energy saved

The total solar fraction accounts for the percentage of the total DHW, heating and cooling needs covered through the solar energy utilization. The total electric efficiency is the average ratio of the total thermal loads (for heating, cooling and domestic hot water) and the electrical consumption of the system (comprising chiller and solar circuits pumps, heat rejection system fans, etc). The primary energy saved is an environmental figure comparing energy needs of the conventional and the renewable solution, in terms of primary energy employed, during a year period. In the study presented, a relative figure is used:

$$PES_{rel} = \frac{PE_{trad} - PE_{SC+}}{PE_{trad}}$$

Depending on the location of the solar combi+ system investigated, and therefore on the solar energy availability, different optimization functions were identified. For Naples applications, it requested that more than 60% of the load are covered through solar energy, the electrical COP is higher than

10, and the primary energy used in the solar combi+ system is lower than the one employed in the traditional system (PES_{rel}>0):

$$Suitable\ solutions = \{solutions \mid SF_{tot} > 60\%, COP_{el} > 10, PES_{rel} > 0\}$$

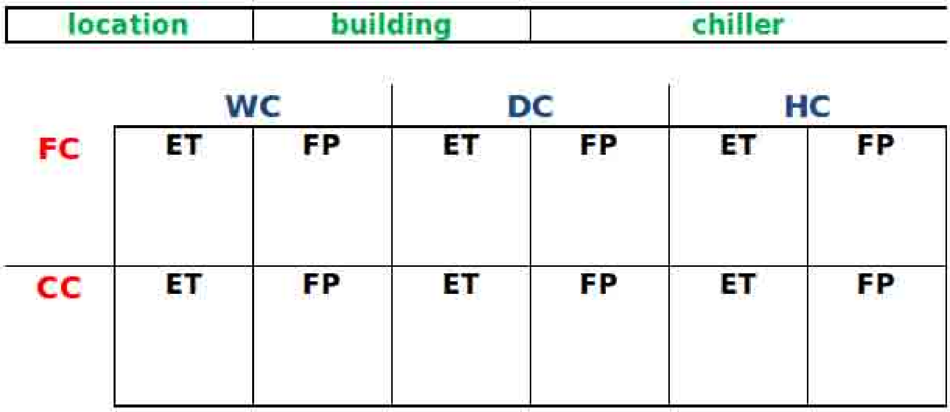
For Toulouse and Strasbourg applications, it is accepted a lower total solar fraction (SF_{tot}>40) as a consequence of the lower available solar irradiation and the irradiation and the reduced correlation between supply and demand. On the other hand, it requires a higher electrical COP, since the heat rejection system electrical consumption is lower, as a consequence of lower summer temperatures:

$$Suitable\ solutions = \{solutions \mid SF_{tot} > 40\%, COP_{el} > 15, PES_{rel} > 0\}$$

Once suitable configurations are assessed, the following step was the selection of the "best" configurations with regard to the three figures mentioned earlier. For every combination of *fixed parameters* (location, application and chiller) three best configurations can, in general, be identified:

- configuration with the highest total solar fraction (the energetic "best" case)
- configuration with the highest total solar fraction (the electrical consumption "best" case)
- configuration with the highest primary energy saved (the environmental "best" case)

In order to give a synthetic representation of the optimal configurations, the table shown in Figure 34 is proposed. Such a table allows evaluating which parameters' combination gives the maximum of the considered selection parameter.



location	building	chiller

	WC		DC		HC	
FC	ET	FP	ET	FP	ET	FP
CC	ET	FP	ET	FP	ET	FP

Figure 34 – Table reporting the optimal configurations. WC = Wet Cooling Tower, DC = Dry Cooler, HC = Hybrid Cooler, FC = Fan Coil, CC = Chilled Ceiling, ET = Evacuated Tubes Collectors, FP = Flat Plate Collectors

In such a table, the *fixed parameters* are indicated in the first row (see Figure 35). A table for every possible combination of *fixed parameters* has to be drawn.

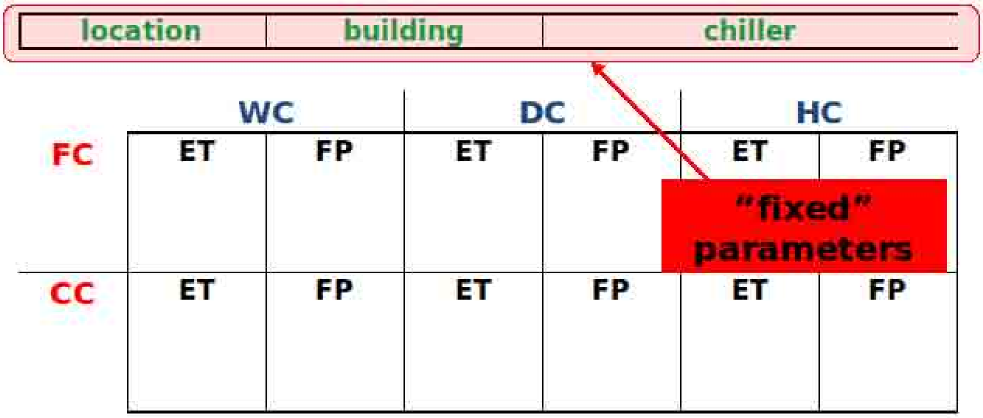


Figure 35 - Table reporting the optimal configuration: *the fixed parameters*

Figure 36 shows the location of the *semi-fixed parameters* within the table. The three heat rejection systems are reported in the columns, the two distribution systems are reported in the rows: for each combination of that two parameters, two solar collector types are possible (evacuated tubes and flat plate).

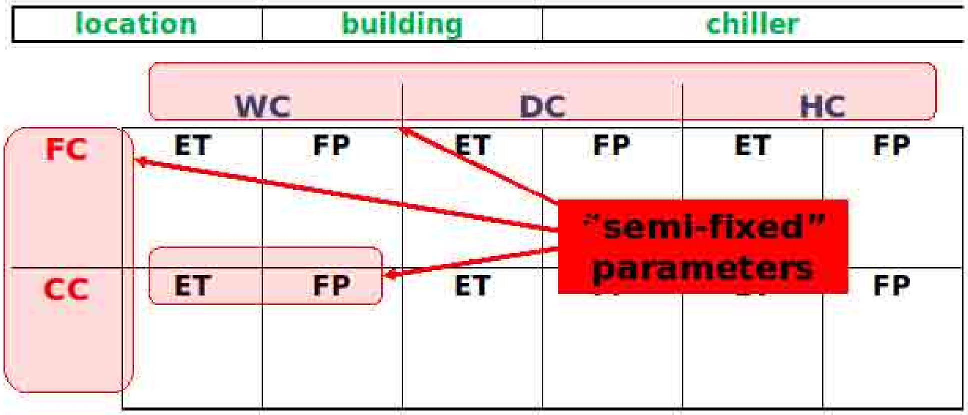
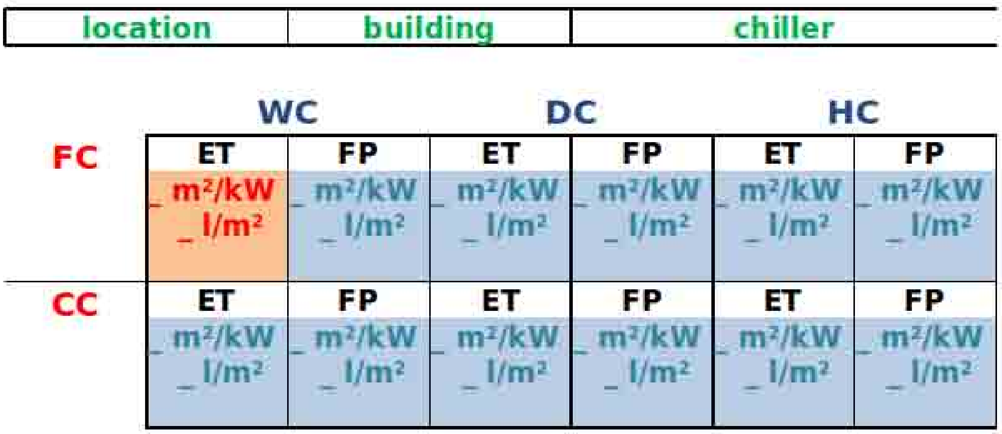


Figure 36 - Table reporting the optimal configuration: *the semi-fixed parameters*

The values of the *free parameters* (collector area and storage volume) are placed within the twelve cells corresponding to all the possible combinations of the *semi-fixed parameters* (see Figure 37). Every cell reports the values of the *free parameters* corresponding to the maximum of the considered selection parameter. Among all these values, the absolute maximum ("best" configuration) is identified.



location	building	chiller

	WC		DC		HC	
	ET	FP	ET	FP	ET	FP
FC	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2
	ET	FP	ET	FP	ET	FP
CC	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2	_ m^2/kW _ l/m^2

Figure 37 - Table reporting the optimal configuration: *the free parameters*

Since the purpose of the project is not to compare technologies and manufacturers, on the contrary it is meant to provide information about solar heating and cooling applications, the analysis was in the end carried out and presented, mixing data from the five chillers considered. A codified reference to the chillers (A to E) is however maintained, since the variability of the results as a function of the machine considered would hide their dependency on the technical solutions adopted.

8.2 Standard Configurations

The final goal of the project is the identification of a reduced number of "standard system configurations", which can be promoted with reasonably good results in typical/average cases, and which are mostly technology independent. The idea is to move from the best configurations (found out chiller by chiller) to good configurations (not dependent on the specific chillers). This approach was adopted since the best energetic-environmental solution might not be the most effective from the point of view of marketing-cost aspects.

A sensitivity analysis was carried out for this purpose, showing the effect of varying technologies employed and sizing of the components on the solar combi+ system performance for different applications and locations. An extended set of performance figures was selected for this exercise; besides the ones already mentioned, two other were considered:

- Cooling Solar Fraction
- Gross Solar Yield

The cooling solar fraction accounts for the percentage of cooling load covered through the solar energy utilization. The gross solar yield measures the solar energy yearly harvested by the system per unit of collectors' area.

Due to the wide variability of the results detected, it was decided to take into account only the three best performing configurations for each set of simulated fixed/semi fixed parameters. Nevertheless, the range of results is still quite large (see Figure 38, Figure 39) as a consequence of the different conditions, technologies and chillers adopted; therefore each set of fixed/semi fixed parameters was discussed separately.

It has to be stated here that not all chillers' manufacturers wanted to simulated the whole set of configurations, since they decided not sell such a configuration, knowing from the beginning the modest performance of their machine for given configuration, or because they do not market that technology. Table 10 shows all the simulated cases for each considered chiller. As it can be seen, only one manufacturer (chiller C) wanted to take into consideration the dry cooler for this analysis on a voluntary basis, due to ambient conditions that complicate the heat rejecting in the two southern locations investigated; therefore, this solution is not discussed in the following. Chiller D was not considered in combination with fan coils and chiller E do not sell solar combi+ systems with evacuated tubes. It is also remembered that only fan coils are considered as a distribution system suitable for office applications.

Two configurations were taken as the reference configurations for the discussion, i.e. CC-FP-WCT for residential and FC-FP-WCT for office buildings.

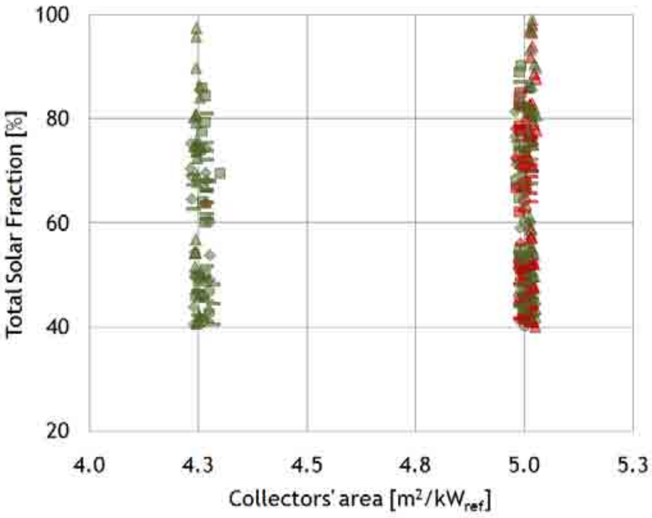


Figure 38 – Total Solar Fraction for all the configurations selected

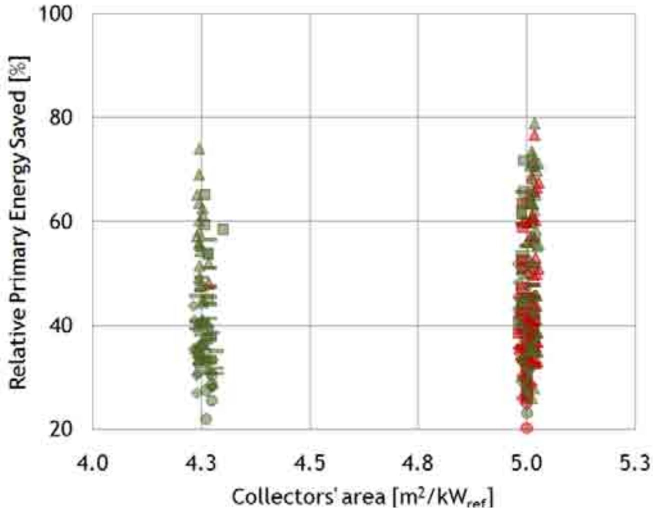


Figure 39 – Relative Primary Energy Saved for all the configurations selected

Table 10 – Simulated configurations for the chillers named from “A” to “E”

	WCT				HC				DC			
	ET		FP		ET		FP		ET		FP	
CC	A	X	A	X	A	X	A	X	A		A	
	B	X	B	X	B	X	B	X	B		B	
	C	X	C	X	C	X	C	X	C	X	C	X
	D	X	D	X	D	X	D	X	D		D	
	E		E	X	E		E	X	E		E	
	ET		FP		ET		FP		ET		FP	
FC	A	X	A	X	A	X	A	X	A		A	
	B	X	B	X	B	X	B	X	B		B	
	C	X	C	X	C	X	C	X	C	X	C	X
	D		D		D		D		D		D	
	E		E	X	E		E	X	E		E	

8.3 Results

In this chapter the results of the analysis described are reported. The best configuration are addressed first; results from the selection of best configurations are reported in Annex I. Then the standard configurations are discussed for each set of simulated parameters. The values discussed are reported in graphs (see Annex II) and in an overall table (see Annex III).

Results are reported as a function of specific collectors' area and storage tank volume: the first figure, reported in m^2/kW_{ref}, relates the collectors' area to the reference chiller power for given heat rejection technology and distribution system used (see D3.3 "General results of virtual case studies" for more information). The second, reported in l/m2, relates the storage volume size to the collectors' area. In this way, components performance, cooling and heating loads are sized in an integrated process.

8.3.1 Best Configurations

The first outcome that can easily be noted is that all the best configurations are related to the largest collectors' area (5 m^2/kW_{ref}) and storage volume (75 l/m^2) simulated. Even though it might seem trivial, it shows values that differ to quite some extent from the ones usually encountered when pure solar cooling systems are considered. Collectors' areas for such plants range in fact between 3.5 and 4.5 m^2/kW_{ref} [10]. This difference is due to the operation of solar combi+ operation also during winters: in fact, even though smaller areas allow to cover rated heat fluxes at the generator of the sorption chillers to cover most of the cooling load at summer time, in winters, larger areas are required if heating and DHW preparation are needed, due to the significantly reduced radiation available; as can be seen in deliverable D4.7 ("Description and Visual Representation of Most Promising Markets"), about the same energy is delivered during 4 months in summer than in the remaining 8 months. A few simulations run, show that an inversion of the trend is obtained at around 7 m^2/kW_{ref}; such big areas were not taken into account in this study, since they hardly could find place on the roof of residential buildings, being far beyond feasibility.

Looking at the performance figures used for the selection of the best configurations, total solar fraction and relative primary energy saved are analyzed first. From the tables in Annex I, it can be seen that the best results are obtained with regard to Naples installations; Toulouse and Strasbourg systems follow. Without going into many details –since this is done for Standard Configurations discussion- the residential applications in Naples feature values of total solar fraction that vary between 67% and 87% for the low consumption building (R60) and 60% - 78% for the average consumption building (R100). Toulouse applications range between 46% and 55% in the case of low consumption building and between 40% and 46% for the average consumption building. Such a large difference, is due on the one side to the higher available radiation in Naples, on the other to the better temporal match between solar energy supplied and heat demand: in Toulouse winter loads are by far prevailing on the cooling ones. The differences between the two houses' types is also due to heating loads since cooling loads are about the same for given location (see Chapter 6).

The same trends are detected when primary energy saved is considered. Naples values vary between 30%-70% and 25%-60% for the R60 and the R100 building. In Toulouse, values vary between 23%-45% and 25%-40% for the R60 and the R100 building respectively. In this case a much larger variation of the performance is noticed mainly in Naples. This behavior is largely related to the heat rejection operation: in Naples, due to high summer temperatures and latent loads (the city is placed on the see), the heat rejection system is used at high regimes for large periods. The electrical loads related to this component can grow to be a relevant percentage of the saved energy, unless a well designed strategy is adopted for its control. Some of the chillers' manufacturers involved in the project already adopted heat rejection control strategies for all the technologies employed (dry cooler, hybrid cooler, wet cooling tower) at the time of the simulations, leading to better results. The control design is in progress for the other companies.

This aspect can be seen also looking at the total electrical efficiency. With regard to this performance parameter, higher values are obtained in Toulouse: between 12 and 24 for the low consumption building (R60), 12 and 30 for the average consumption building (R100) in Naples, between 24 and 50 for the R60 building and 30 and 55 for the R100 in Toulouse. As can be seen higher values are also obtained with respect to the R100 buildings, due to the higher ratio between heating and cooling loads. The total electrical efficiency becomes an issue, when fan coils are considered as the distribution system: in this case lower temperatures have to be delivered (chillers inlet temperatures are 12°C for fan coils and 18°C for chilled ceilings); therefore, higher heat fluxes are conveyed to the heat rejection system. That leads to only few cases which total electrical efficiency passes the selection through the optimization functions.

This issue becomes even more severe, if office applications are considered (see Table 13, Table 16 and Table 17). Total electrical efficiencies vary from about 11 in Naples and 15 in Toulouse (i.e. the lower limits of the optimization functions) to around 25 in Strasbourg. Moreover, only the performance of chiller "A" were selected (just one case was taken for chiller "E" in Strasbourg).

For chiller "A" in office applications, the relative PES ranges between 63% and 78% in Naples, 55% and 71% in Toulouse and 26% and 40% in Strasbourg. The total solar fraction approaches the unity in Naples, varies between 80%

and 90% in Toulouse and ranges between 50% and 60% in Strasbourg. If compared to residential building applications, due to negligible DHW loads, the ratio between winter and summer loads increases. Therefore, the total solar fraction is significantly higher, while the primary energy saved is fully comparable. The discussion above shows that in office applications a higher percentage of the loads is covered, to the price of an higher electrical energy consumption (i.e. heating and DHW preparation require very low electrical energy, mostly related to the recirculation pumps, no heat rejection system is needed).

8.3.2 Standard Configurations

In this section, the results of the sensitivity analysis carried out is presented, to show the effect of varying technologies employed and sizing of the components on the system operation. In this way standard configurations, with performance comparable to the best ones, were individuated. The performance figures used for the discussion were:

- total solar fraction
- cooling solar fraction
- relative primary energy saved
- total electrical efficiency
- gross solar yield

The values discussed are reported in graphs (see Annex II) and in an overall table (see Anne III). The graphs discussed in the following paragraphs are setup like in Figure 40: on the y-axis the performance figure is reported versus the specific collectors' area.

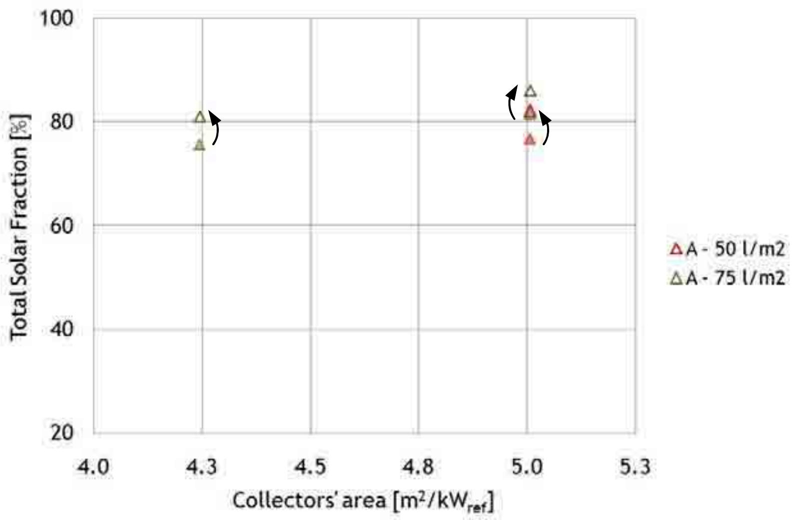


Figure 40 – Example of comparison chart shown in Annex II

Storage tank specific volume is stated through red (50 l/m^2) and green (75 l/m^2) colors. A different symbol is used for each chiller: chiller A = triangle, B = circle, C = line, D = diamond, E = square. Finally, since the graphs serve to comparing technologies, a reference configuration -i.e CC-FP-WCT for residential and FC-FP-WCT for office buildings- is always shown with a solid symbol, while "compared" technologies are specified with a void one. Therefore, in Figure 40, the solid and the void green triangles at 4.3 m^2/kW_{ref} have to be considered if comparison between technologies is sought. The effect of sizing is illustrated through x-axis and colors.

7.3.2.1 Residential Buildings

Solar combi+ systems performance in residential buildings are investigated first. Figure 41 and Figure 42 show total solar fraction figures for Naples and Toulouse respectively. Again, the performance for all chillers considered range between around 60% and 85% in Naples and between 40% and 60% in Toulouse.

Analyzing the effect of the sizing procedure, it is shown (see blue arrows) that the result of reducing the storage tank volume of 33% (from 75 l/m^2 to 50 l/m^2) is a slight reduction of total solar fraction in between 3% and 5%. The effect of additionally reducing the collectors area (14% from 5m^2/kW_{ref} to 4.3m^2/kW_{ref}) is an extra drop of about 4% of the performance. Therefore, from this point of view, a moderate decrease of the solar utilization efficacy is reached. On the other hand, a significant reduction of the investment costs might be obtained depending on the technologies adopted.

Figure 41a) and Figure 42a) display the effect of the solar collector type. The black arrows show the performance change for some considered configurations. In Naples the evacuated tubes allow increasing the performance of 5 to 7%, while in Toulouse the gain is higher, but still limited to around 10%. As can be seen in Figures b) and c), the consequence of changing heat rejection system or distribution system is more or less no variation in operation. The impact of the building efficiency (Figure d)) is a reduction of 7 to 10% when going from R60 to R100. In absolute terms the variations are about the same in Naples and in Toulouse, resulting in higher impacts (in relative terms) in Toulouse.

The same discussion holds if cooling solar fraction is considered. In general, these values are higher than the corresponding total solar fraction ones: in Naples, except for one point, they are in the range 70%-95%, whereas in Toulouse they vary from 50% to 95%. However, while in Naples the points are grouped together, a large variability of the values is detected in Toulouse: in the first case in fact high temperatures can be reached with both collectors technologies and all chillers can reach their rated conditions for most of the time. In the latter, on the contrary, being lower the radiation levels, only machines working at lower temperatures can reach nominal operating conditions for large periods of time. This aspect is also proved by figures a): Figure 43a) shows a variability of about 5% between flat plate and evacuated tubes collectors; in Figure 44a) a rise of cooling solar fraction of about 10-15% is noticed when passing to evacuated tubes collectors, which guaranty higher temperature levels.

For the same reason, chilled ceilings give slightly better results than fan coils when only cooling is considered (see figures c)): while in winter the two distribution systems work at similar temperature levels, in summer, fan coils work at significantly lower temperatures with respect to chilled ceilings, leading to lower heat fluxes available at the evaporator of the chillers. This is clearly visible if cooling solar fraction is taken into account; the effect is mostly mitigated by winter operation if total solar fraction is contemplated. With respect to this figure, higher variations are encountered in Naples (5-7%) since higher latent loads are experienced.

Again, the effect of the heat rejection system (figures b)) and buildings' efficiency are not significant. The latter result is due to the fact that roughly the same cooling loads are assessed in the two constructions' categories.

If relative primary energy saved is regarded (Figure 45 and Figure 46), the effect of reducing the storage volume from 75 l/m^2 to 50 l/m^2 is a quite significant reduction of about 9-10%. The outcome of additionally reducing the collectors area is a drop of the values calculated of around 12-17%. Thus, in this case, the sizing of the components produces major consequences on the system performance; since the primary energy saved is linearly related to the "money spared" through the utilization of the system, the reduction of the investment costs has to be critically weighted with the increase of running costs.

Relative primary energy saved was assessed between 30% and 70% in Naples and between 20% and 50% in Toulouse. With regard to this figure, a much larger spread of data is obtained in Naples than in Toulouse, depending on the chiller considered. As already noticed in chapter 8.3.1, in fact, in Naples the heat rejection system is used for longer periods at higher rates, resulting in large electrical energy consumption in case of unwise heat rejection system use. Nevertheless, for given chiller and configuration, better performance is obtained in Naples: it might be argued therefore, that the ratio between solar energy harvested and electrical energy consumption for the operation of the solar combi+ plant is anyhow more favorable in Naples than in Toulouse.

Figure 45a) and Figure 46a) show a difference in relative primary energy saved of about 10% in Naples and 5% in Toulouse, depending on the collectors technology used. This corresponds to total variations in a range of 15-30%.

Once again, the effect of the heat rejection technology employed, is slightly relevant. Deviations of about 2-3% are noticed both in Naples and in Toulouse (i.e. Hybrid cooler less efficient than the wet cooling tower). As already observed, fan coils utilization (figures c)) requires a higher heat rejection, producing larger electrical energy consumption; the effect is still very limited in Toulouse (apart for chiller B), while it might result in a quite large reduction of the system performance (5-10%) in Naples. The primary energy saved is lower for buildings with larger loads. Cuts of about 3-7% from R60 to R100 are evaluated. In absolute terms the variations are about the same in Naples and in Toulouse, yet resulting in higher impacts in Toulouse.

The latter analysis holds also regarding the total electric efficiency (Figure 47 and Figure 48): higher summer electrical energy consumption brings to much lower data in Naples (i.e. range 10-25%) than in Toulouse (range 25-40%).

Finally, Figure 49 and Figure 50 show the results relative to the gross solar yield. This figure, accounting for the solar energy harvested per unit collectors' area, is reported to compare performance of solar combi+ system with a simple plant for the preparation of DHW, which generally allows for a yearly capture of 300-400 kWh/m^2/year depending on the location. The simulated configurations perform all better than the reported values; nonetheless, a strong dependence on the collectors area is evident: smaller areas work better since the ratio between the energy gathered and the loads is lower; the energy is therefore better used in the system and the return temperature to the collectors is lower. This produces lower thermal losses toward the environment. For the same reason much lower stagnation is encountered.

Once again, better absolute performance are evaluated in Naples (400-600 kWh/m^2/year) than in Toulouse (300-500 kWh/m^2/year), due to higher radiation and average ambient temperatures in southern countries. The effect of varying the collectors area between 4.3 to 5.0 m^2/kW$_{ref}$ is a reduction of gross solar yield of 40-50 kWh/m^2/year; the outcome of using smaller storage tanks is more limited (i.e. around 10 kWh/m^2/year). This reduction can be recovered by using evacuated tubes rather than flat plate collectors (figures a)).

With regard to this figure, better working conditions are obtained with hybrid cooler, fan coils and R100 house, since in all those cases a lower ratio between solar gain and loads is encountered.

7.3.2.2 Office Buildings

As can be seen in Chapter 6, whereas the heating loads of the office applications are completely comparable with those of the residential buildings, the cooling loads are much higher: values ranging from 34 to 81 kWh/m^2/year are used for the simulations. Therefore, the operation in cooling conditions overtakes the performance of the solar combi+ system.

The massive cooling loads, together with the use of fan coils as distribution system, lead to very high electrical energy consumption, resulting in very low total electric efficiency values: in Naples and Toulouse only chiller “A” performance exceed the lower limits of 10 and 15 respectively. In Strasbourg, also chiller “E” slightly tops the limit (see Figure 60 to Figure 62). Chillers “B” and “C” did not provide any suitable result; chiller “D” was not simulated with fan coils. In any case, data very close to the lower limit were detected, apart for chiller “A” operated with evacuated tubes in Strasbourg: for this configurations values up to 25 were obtained.

Total solar fraction varies between 90% and 95% in Naples, 75% and 90% in Toulouse and 50-70% in Strasbourg (Figure 51 to Figure 53). Figures a) show that the use of evacuated tubes collectors do not produce any performance increase. The better technology becomes increasingly beneficial as far as the application is moved to Toulouse (+2% - 3%) and to Strasbourg (+10% in the only comparable configuration).

Cooling solar fraction data (Figure 54 to Figure 56) range again between 90 and 95% in Naples, since heating loads are negligible with respect to cooling ones. In Toulouse and Strasbourg they also approach the unity. The effect of heat rejection technology is yet negligible for all configurations presented.

Relative primary energy saved varies in the range 55-75% in Naples and 45-70% in Toulouse; much lower values are seen in Strasbourg, where simulations run range between 25% and 40% (see Figure 57 to Figure 59). This figure is strongly affected by the collectors technology employed: differences between 10% and 15% were evaluated depending on the location.

Finally, Figure 63 to Figure 65 show the performance of the solar combi+ system in terms of gross solar yield. The figure is clearly dependent on the collectors area, the variation being less and less significant the application moving to north, from Naples to Strasbourg. Moreover, moving northern the gross solar yield decreases toward the lower limit of 300 kWh/m^2/year: in Strasbourg the applications analyzed slightly exceed such a limit.

8.3.3 Simulations without Backup Heater

The performance of the best configurations assessed were also evaluated in a configuration where the backup heater was not used for driving the sorption chiller. In particular, results from the simulations relating to the residential applications are here discussed: wet cooling tower configurations are presented both for R60 and R100 applications, and for fan coils and chilled ceiling distribution systems. Office applications are not discussed due to the already extremely high solar fractions reported in the previous paragraph. Collectors' area of 5 m^2/kW_{ref} and storage volume of 75 l/m^2 were considered.

Solar coverage of cooling load -which in this case replaces the cooling solar fraction figure since no comparison with fossil fuel operation is applicable- decreases if the backup heater is not used. This is due to the fact that the heater allows higher temperatures at chillers inlet (and also at the outlet); therefore, also higher temperatures at the collectors are temporarily produced and thus higher solar fractions. Chillers working at average lower temperatures feature cooling solar fractions that drop of around 3%-10% with respect to the reference cases in which backup heater is considered. In Naples the decrease is around 3%-5%, while higher values are encountered in Toulouse, i.e. around 5%-10%: again the better matching between solar energy availability and heat demand in Naples, allows for higher average temperatures at the chillers (and at the DHW tank), consequently mitigating the lack of backup heater.

The lower temperatures at the collectors produce a slightly enhanced gross solar yield in the range of 1%-2%.

The largest effects are however encountered if yearly relative primary energy is considered. The saving of fossil fuel results in a relative increase of this figure in a range of 10%-30%. For the same reasons reported above, the best effects are encountered in Naples where 20%-30% higher savings are obtained, while in Toulouse more moderate increases are achieved around 10%.

8.4 Conclusions

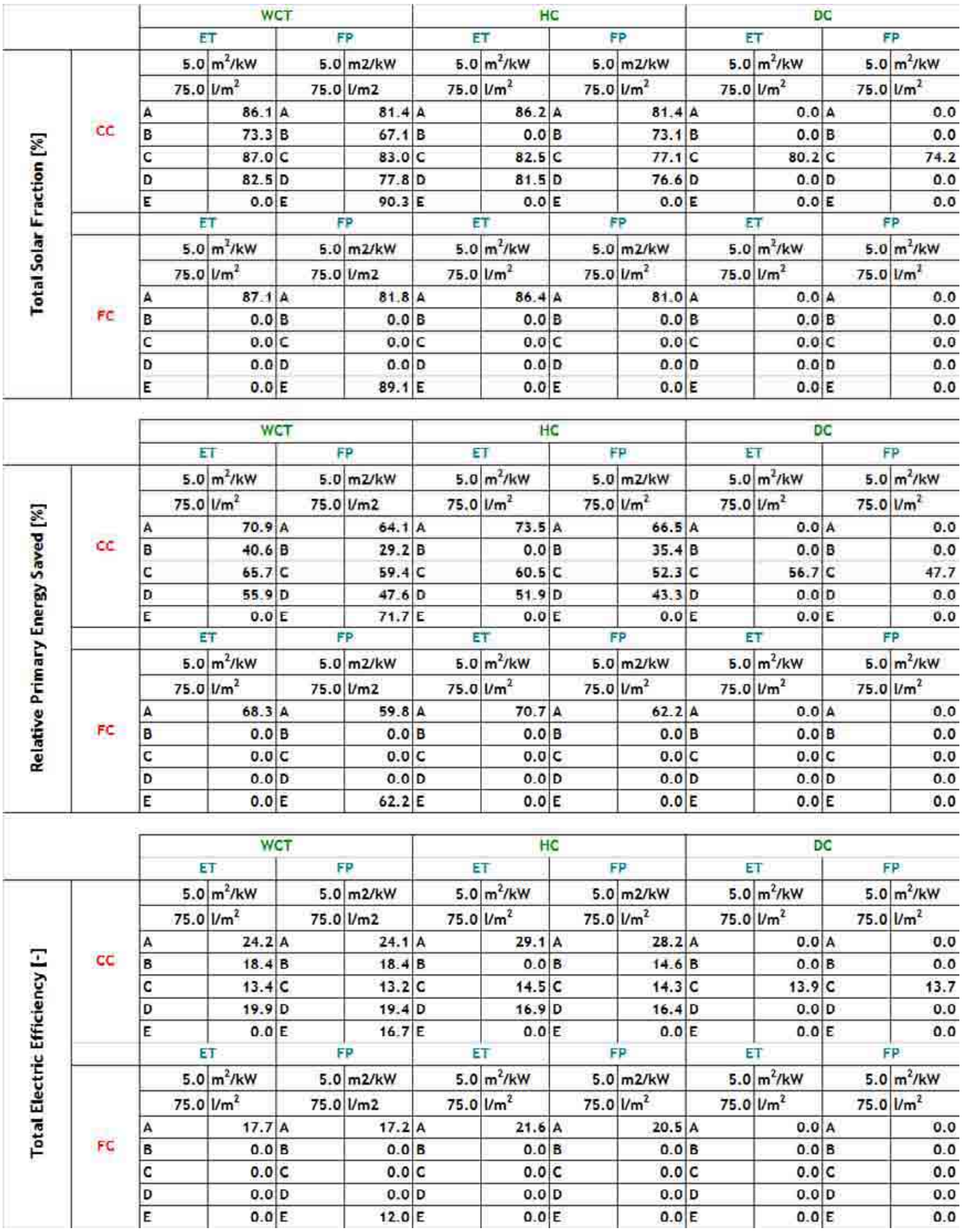
In general, best performing plants are encountered where high radiation is coupled with high cooling loads and modest needs for heating and DHW preparation (i.e. high ration between suitable solar energy and heat demand), as residential applications. In fact, even though office applications present the highest cooling and total solar fractions, they also show limited performance in terms of total electric efficiency (large electrical energy consumption at heat rejection) and gross solar yield (low solar energy capture at lower temperatures for DHW preparation and during mid seasons when cooling or heating is not needed).

The technologies affecting mostly the operation of the solar combi+ system are the solar collectors and the heat rejection. Evacuated tubes collectors allow (obviously) better performance, being much more expensive than flat plate ones (around double price on average); consequently, the use of one or the other type has to be weighted carefully. Two types of heat rejection system were discussed in the document: a technology clearly prevailing on the other could not be assessed. However, it was shown how electrical consumption for heat rejection can be a large part of the total “fossil” energy consumption, in some cases affecting primary energy savings to a large extent. With regard to the latter figure, office and residential application present about the same maximum values. More cases were presented regarding residential applications: here minimum primary energy savings can easily be half (25-30%) of maximum values computed (60-70%). Much work has to be carried out therefore to reduce gas usage for heating and driving the chiller, and to minimize electrical energy consumption for heat rejection and fluids pumping through the system, through energy efficiency of buildings and wise control strategies of the plants. Primary energy saved is also the most affected by system sizing; reducing collectors’ areas below the values analyzed brings to highly reduced performance: around 15% drop in yearly primary energy saved is evaluated going from 5 to 4.3 m^2/kW_{ref} area.

The simulations performed are based on simplified models of the buildings, the chillers and the other mentioned components. Therefore they provide approximate estimations of the real behaviour of the system, meant to give a view of the facts and sizes. Moreover, the standard configurations are selected from a purely technical point of view; manufacturers and suppliers take into consideration also cost and marketing figures for the setup of their solutions. The latter are discussed in the reports on the manufacturers package solutions.

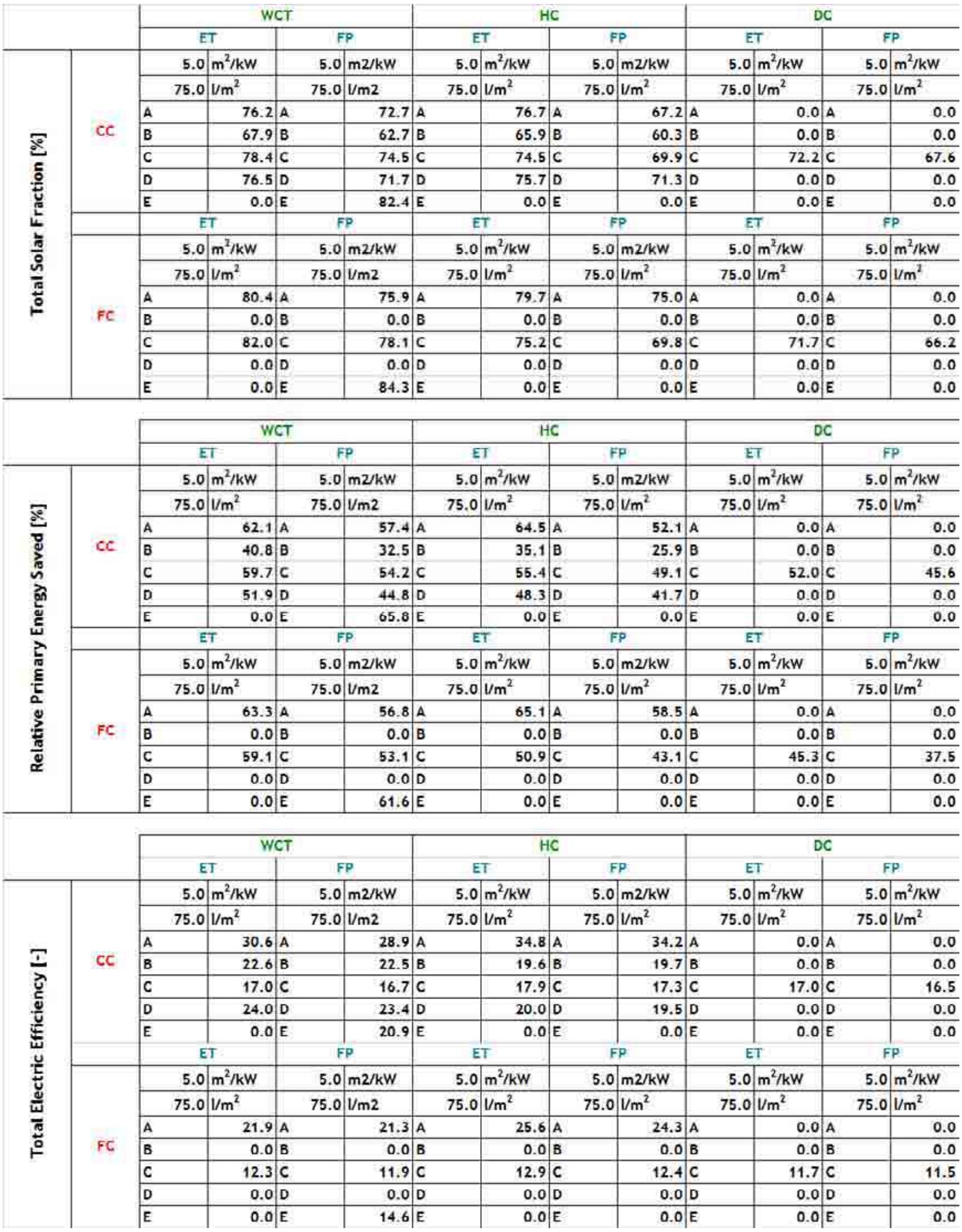
8.5 Annex I – Best configurations

Table 11 – Naples, residential R60 configurations



		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	86.1	A	81.4	A	86.2	A	81.4	A	0.0	A	0.0
		B	73.3	B	67.1	B	0.0	B	73.1	B	0.0	B	0.0
		C	87.0	C	83.0	C	82.5	C	77.1	C	80.2	C	74.2
		D	82.5	D	77.8	D	81.5	D	76.6	D	0.0	D	0.0
		E	0.0	E	90.3	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	87.1	A	81.8	A	86.4	A	81.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	89.1	E	0.0	E	0.0	E	0.0	E	0.0
		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	70.9	A	64.1	A	73.5	A	66.5	A	0.0	A	0.0
		B	40.6	B	29.2	B	0.0	B	35.4	B	0.0	B	0.0
		C	65.7	C	59.4	C	60.5	C	52.3	C	56.7	C	47.7
		D	55.9	D	47.6	D	51.9	D	43.3	D	0.0	D	0.0
		E	0.0	E	71.7	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	68.3	A	59.8	A	70.7	A	62.2	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	62.2	E	0.0	E	0.0	E	0.0	E	0.0
		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	24.2	A	24.1	A	29.1	A	28.2	A	0.0	A	0.0
		B	18.4	B	18.4	B	0.0	B	14.6	B	0.0	B	0.0
		C	13.4	C	13.2	C	14.5	C	14.3	C	13.9	C	13.7
		D	19.9	D	19.4	D	16.9	D	16.4	D	0.0	D	0.0
		E	0.0	E	16.7	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	17.7	A	17.2	A	21.6	A	20.5	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	12.0	E	0.0	E	0.0	E	0.0	E	0.0

Table 12 - Naples, residential R100 configurations



			WCT		HC		DC	
			ET	FP	ET	FP	ET	FP
Total Solar Fraction [%]	CC		5.0 m^2/kW	5.0 m2/kW	5.0 m^2/kW	5.0 m2/kW	5.0 m^2/kW	5.0 m^2/kW
			75.0 l/m^2	75.0 l/m2	75.0 l/m^2	75.0 l/m^2	75.0 l/m^2	75.0 l/m^2
		A	76.2	72.7	76.7	67.2	0.0	0.0
		B	67.9	62.7	65.9	60.3	0.0	0.0
		C	78.4	74.5	74.5	69.9	72.2	67.6
		D	76.5	71.7	75.7	71.3	0.0	0.0
		E	0.0	82.4	0.0	0.0	0.0	0.0
			ET	FP	ET	FP	ET	FP
	FC		5.0 m^2/kW	5.0 m2/kW	5.0 m^2/kW	5.0 m2/kW	5.0 m^2/kW	5.0 m^2/kW
			75.0 l/m^2	75.0 l/m2	75.0 l/m^2	75.0 l/m^2	75.0 l/m^2	75.0 l/m^2
		A	80.4	75.9	79.7	75.0	0.0	0.0
		B	0.0	0.0	0.0	0.0	0.0	0.0
		C	82.0	78.1	75.2	69.8	71.7	66.2
		D	0.0	0.0	0.0	0.0	0.0	0.0
		E	0.0	84.3	0.0	0.0	0.0	0.0

			WCT		HC		DC	
			ET	FP	ET	FP	ET	FP
Relative Primary Energy Saved [%]	CC		5.0 m^2/kW	5.0 m2/kW	5.0 m^2/kW	5.0 m2/kW	5.0 m^2/kW	5.0 m^2/kW
			75.0 l/m^2	75.0 l/m2	75.0 l/m^2	75.0 l/m^2	75.0 l/m^2	75.0 l/m^2
		A	62.1	57.4	64.5	52.1	0.0	0.0
		B	40.8	32.5	35.1	25.9	0.0	0.0
		C	59.7	54.2	55.4	49.1	52.0	45.6
		D	51.9	44.8	48.3	41.7	0.0	0.0
		E	0.0	65.8	0.0	0.0	0.0	0.0
			ET	FP	ET	FP	ET	FP
	FC		5.0 m^2/kW	5.0 m2/kW	5.0 m^2/kW	5.0 m2/kW	5.0 m^2/kW	5.0 m^2/kW
			75.0 l/m^2	75.0 l/m2	75.0 l/m^2	75.0 l/m^2	75.0 l/m^2	75.0 l/m^2
		A	63.3	56.8	65.1	58.5	0.0	0.0
		B	0.0	0.0	0.0	0.0	0.0	0.0
		C	59.1	53.1	50.9	43.1	45.3	37.5
		D	0.0	0.0	0.0	0.0	0.0	0.0
		E	0.0	61.6	0.0	0.0	0.0	0.0

			WCT		HC		DC	
			ET	FP	ET	FP	ET	FP
Total Electric Efficiency [-]	CC		5.0 m^2/kW	5.0 m2/kW	5.0 m^2/kW	5.0 m2/kW	5.0 m^2/kW	5.0 m^2/kW
			75.0 l/m^2	75.0 l/m2	75.0 l/m^2	75.0 l/m^2	75.0 l/m^2	75.0 l/m^2
		A	30.6	28.9	34.8	34.2	0.0	0.0
		B	22.6	22.5	19.6	19.7	0.0	0.0
		C	17.0	16.7	17.9	17.3	17.0	16.5
		D	24.0	23.4	20.0	19.5	0.0	0.0
		E	0.0	20.9	0.0	0.0	0.0	0.0
			ET	FP	ET	FP	ET	FP
	FC		5.0 m^2/kW	5.0 m2/kW	5.0 m^2/kW	5.0 m2/kW	5.0 m^2/kW	5.0 m^2/kW
			75.0 l/m^2	75.0 l/m2	75.0 l/m^2	75.0 l/m^2	75.0 l/m^2	75.0 l/m^2
		A	21.9	21.3	25.6	24.3	0.0	0.0
		B	0.0	0.0	0.0	0.0	0.0	0.0
		C	12.3	11.9	12.9	12.4	11.7	11.5
		D	0.0	0.0	0.0	0.0	0.0	0.0
		E	0.0	14.6	0.0	0.0	0.0	0.0

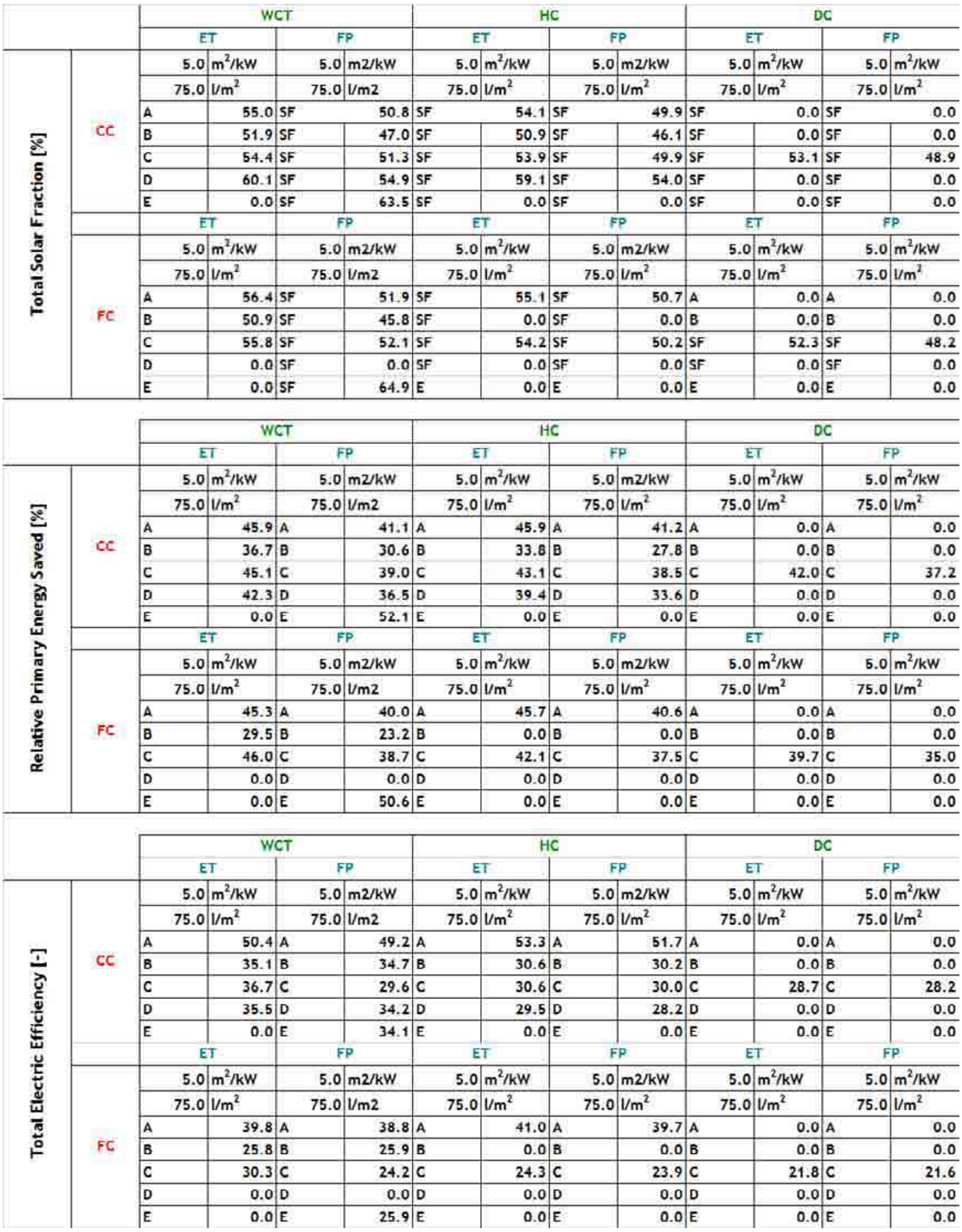
Table 13 – Naples, office configurations

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	97.5	A	93.3	A	99.0	A	96.6	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	72.8	A	63.5	A	78.9	A	71.4	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	11.2	A	11.1	A	12.9	A	11.5	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0

Table 14 – Toulouse, residential R60 configurations



		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	55.0	SF	50.8	SF	54.1	SF	49.9	SF	0.0	SF	0.0
		B	51.9	SF	47.0	SF	50.9	SF	46.1	SF	0.0	SF	0.0
		C	54.4	SF	51.3	SF	53.9	SF	49.9	SF	53.1	SF	48.9
		D	60.1	SF	54.9	SF	59.1	SF	54.0	SF	0.0	SF	0.0
		E	0.0	SF	63.5	SF	0.0	SF	0.0	SF	0.0	SF	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	56.4	SF	51.9	SF	55.1	SF	50.7	A	0.0	A	0.0
		B	50.9	SF	45.8	SF	0.0	SF	0.0	B	0.0	B	0.0
		C	55.8	SF	52.1	SF	54.2	SF	50.2	SF	52.3	SF	48.2
		D	0.0	SF	0.0	SF	0.0	SF	0.0	SF	0.0	SF	0.0
		E	0.0	SF	64.9	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	45.9	A	41.1	A	45.9	A	41.2	A	0.0	A	0.0
		B	36.7	B	30.6	B	33.8	B	27.8	B	0.0	B	0.0
		C	45.1	C	39.0	C	43.1	C	38.5	C	42.0	C	37.2
		D	42.3	D	36.5	D	39.4	D	33.6	D	0.0	D	0.0
		E	0.0	E	52.1	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	45.3	A	40.0	A	45.7	A	40.6	A	0.0	A	0.0
		B	29.5	B	23.2	B	0.0	B	0.0	B	0.0	B	0.0
		C	46.0	C	38.7	C	42.1	C	37.5	C	39.7	C	35.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	50.6	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	50.4	A	49.2	A	53.3	A	51.7	A	0.0	A	0.0
		B	35.1	B	34.7	B	30.6	B	30.2	B	0.0	B	0.0
		C	36.7	C	29.6	C	30.6	C	30.0	C	28.7	C	28.2
		D	35.5	D	34.2	D	29.5	D	28.2	D	0.0	D	0.0
		E	0.0	E	34.1	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	39.8	A	38.8	A	41.0	A	39.7	A	0.0	A	0.0
		B	25.8	B	25.9	B	0.0	B	0.0	B	0.0	B	0.0
		C	30.3	C	24.2	C	24.3	C	23.9	C	21.8	C	21.6
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	25.9	E	0.0	E	0.0	E	0.0	E	0.0

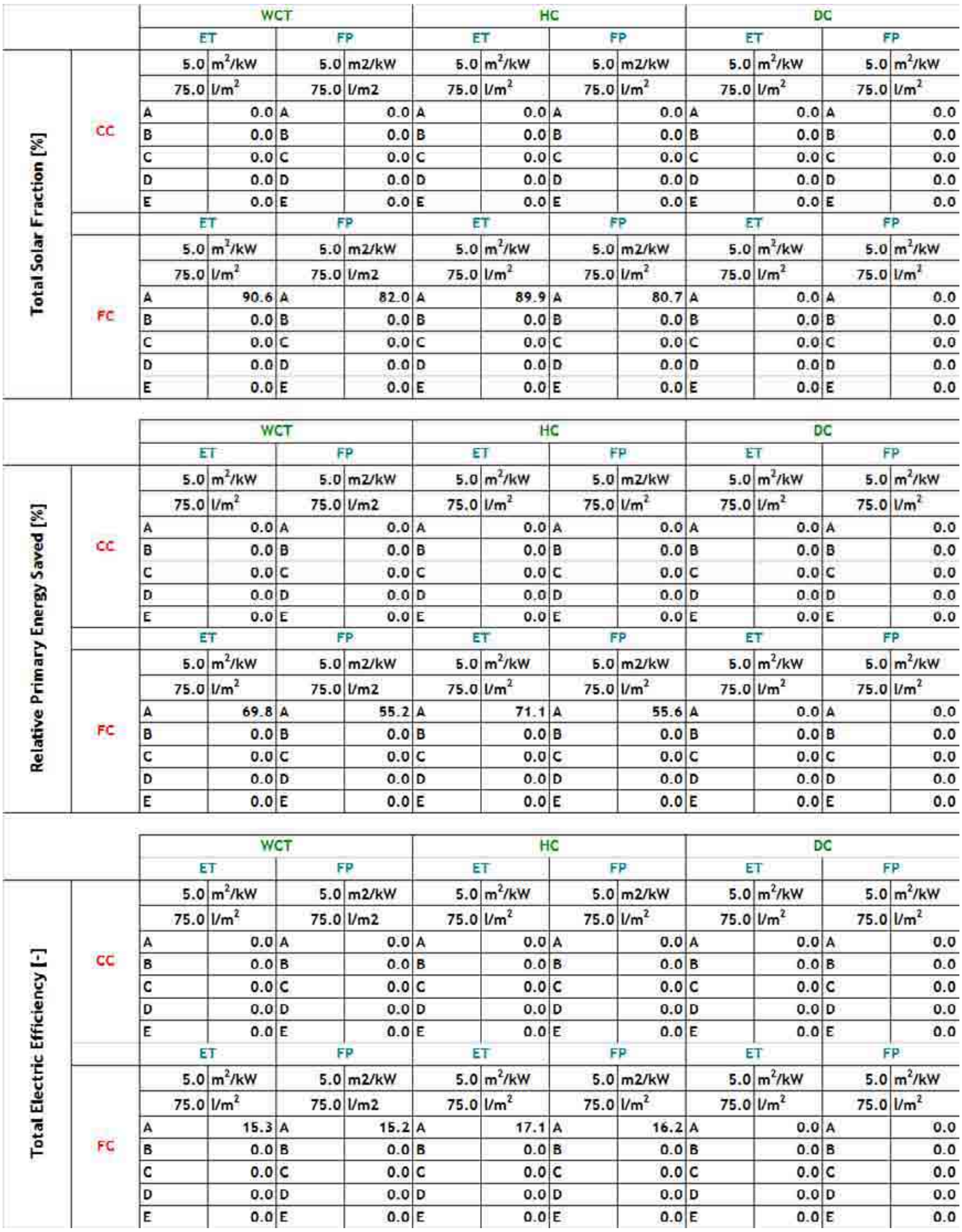
Table 15 - Toulouse, residential R100 configurations

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	46.5	A	43.3	A	44.7	A	41.6	A	0.0	A	0.0
		B	43.7	B	40.4	B	43.3	B	0.0	B	0.0	B	0.0
		C	46.2	C	44.0	C	45.9	C	43.0	C	45.2	C	42.3
		D	48.9	D	45.3	D	48.3	D	44.4	D	0.0	D	0.0
		E	0.0	E	53.2	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	46.6	A	43.1	A	45.3	A	42.0	A	0.0	A	0.0
		B	43.1	B	0.0	B	41.8	B	0.0	B	0.0	B	0.0
		C	46.7	C	44.4	C	45.4	C	42.7	C	44.1	C	41.3
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	54.5	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	40.4	A	36.9	A	39.2	A	35.7	A	0.0	A	0.0
		B	33.2	B	29.5	B	31.6	B	0.0	B	0.0	B	0.0
		C	40.0	C	36.0	C	38.7	C	35.5	C	37.8	C	34.6
		D	35.7	D	31.8	D	33.4	D	29.3	D	0.0	D	0.0
		E	0.0	E	45.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	38.8	A	35.0	A	38.7	A	35.1	A	0.0	A	0.0
		B	28.1	B	0.0	B	24.2	B	0.0	B	0.0	B	0.0
		C	40.1	C	35.6	C	37.3	C	34.3	C	35.5	C	32.5
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	44.0	E	0.0	E	0.0	E	0.0	E	0.0

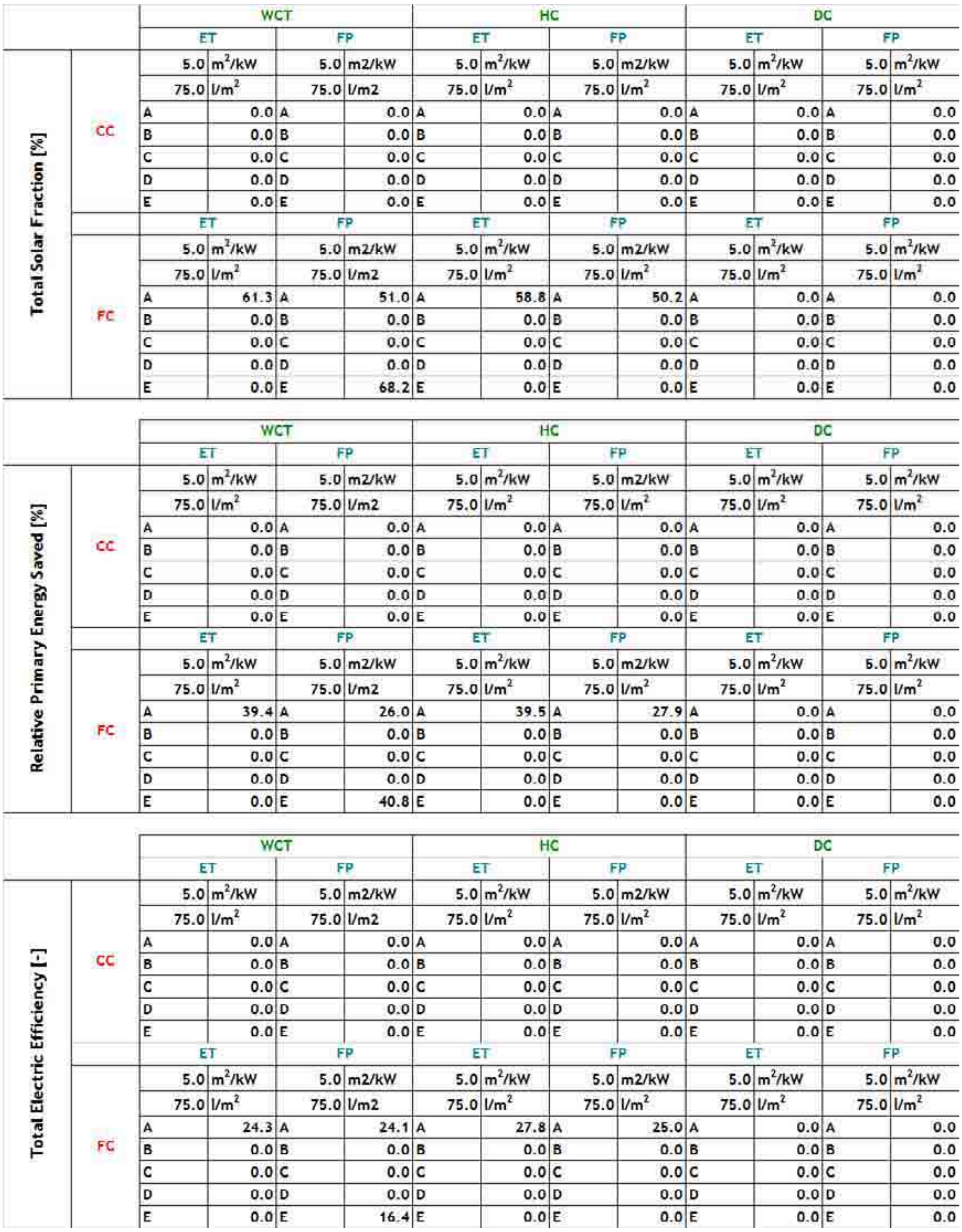
		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	51.7	A	50.6	A	54.7	A	53.0	A		A	0.0
		B	47.1	B	46.8	B	41.1	B	0.0	B	0.0	B	0.0
		C	51.8	C	42.9	C	42.8	C	42.0	C	39.5	C	38.8
		D	47.3	D	45.5	D	38.3	D	36.9	D	0.0	D	0.0
		E	0.0	E	46.5	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	41.2	A	40.2	A	42.3	A	41.1	A	0.0	A	0.0
		B	35.0	B	0.0	B	28.6	B	0.0	B	0.0	B	0.0
		C	43.2	C	35.4	C	34.1	C	33.6	C	30.1	C	29.9
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	36.2	E	0.0	E	0.0	E	0.0	E	0.0

Table 16 - Toulouse, office configurations



		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	90.6	A	82.0	A	89.9	A	80.7	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	69.8	A	55.2	A	71.1	A	55.6	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	15.3	A	15.2	A	17.1	A	16.2	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0

Table 17 - Strasbourg, office configurations



		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Solar Fraction [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	61.3	A	51.0	A	58.8	A	50.2	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	68.2	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Relative Primary Energy Saved [%]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	39.4	A	26.0	A	39.5	A	27.9	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	40.8	E	0.0	E	0.0	E	0.0	E	0.0

		WCT				HC				DC			
		ET		FP		ET		FP		ET		FP	
Total Electric Efficiency [-]	CC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	0.0	A	0.0	A	0.0	A	0.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	0.0	E	0.0	E	0.0	E	0.0	E	0.0
		ET		FP		ET		FP		ET		FP	
	FC	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m2/kW	5.0	m^2/kW	5.0	m^2/kW
		75.0	l/m^2	75.0	l/m2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2	75.0	l/m^2
		A	24.3	A	24.1	A	27.8	A	25.0	A	0.0	A	0.0
		B	0.0	B	0.0	B	0.0	B	0.0	B	0.0	B	0.0
		C	0.0	C	0.0	C	0.0	C	0.0	C	0.0	C	0.0
		D	0.0	D	0.0	D	0.0	D	0.0	D	0.0	D	0.0
		E	0.0	E	16.4	E	0.0	E	0.0	E	0.0	E	0.0

8.6 Standard Configurations Charts

In the following charts, performance figure is reported on the y-axis the versus the specific collectors' area on te x-axis.

Storage tank specific volume is stated through red (50 l/m^2) and green (75 l/m^2) colors.

A different symbol is used for each chiller: chiller A = triangle, B = circle, C = line, D = diamond, E = square.

Since the graphs serve to comparing technologies, a reference configuration - i.e CC-FP-WCT for residential and FC-FP-WCT for office buildings - is always shown with a solid symbol, while "compared" technologies are specified with a void one.

8.6.1 Total Solar Fraction - Residential

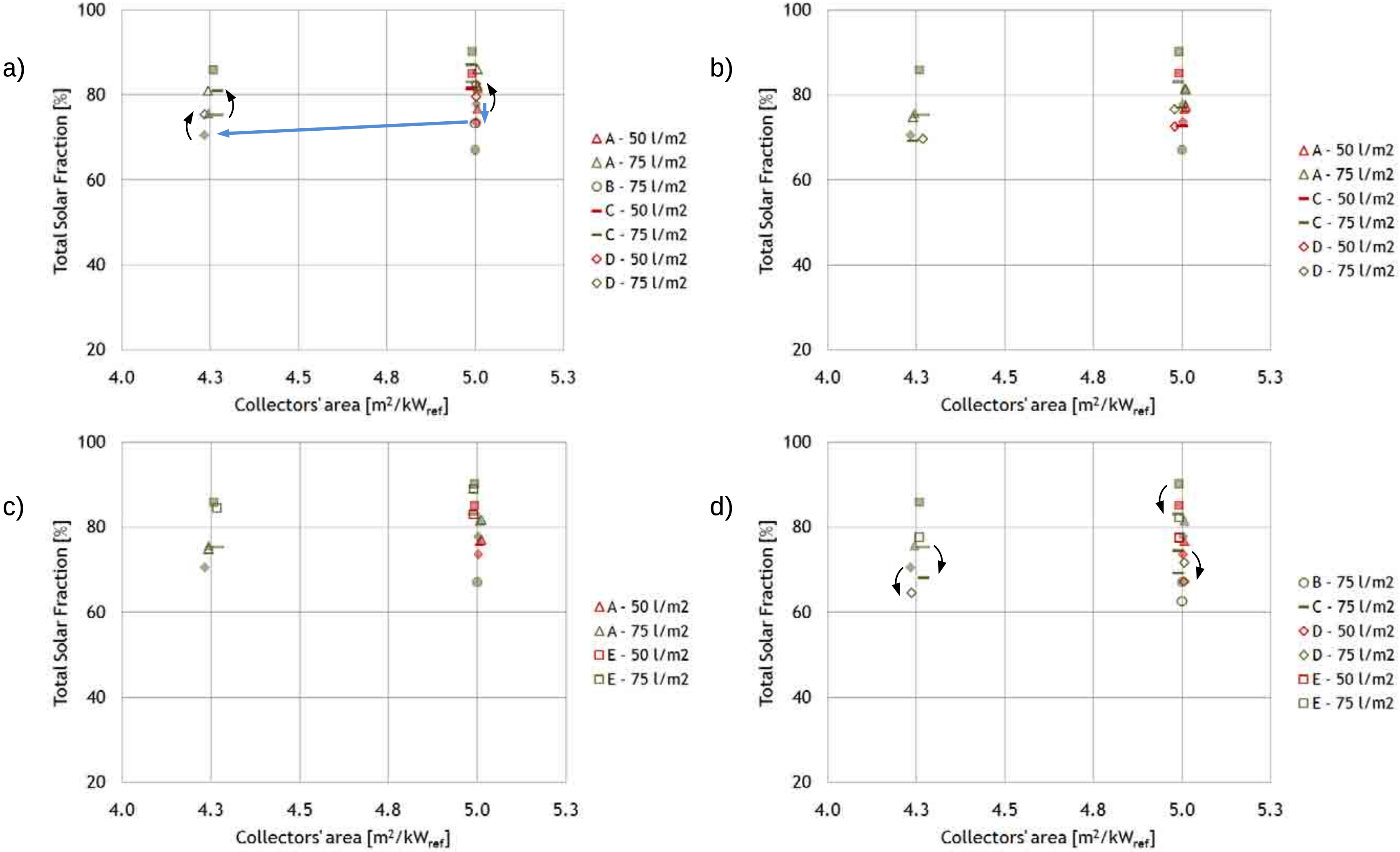


Figure 41 – Naples, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

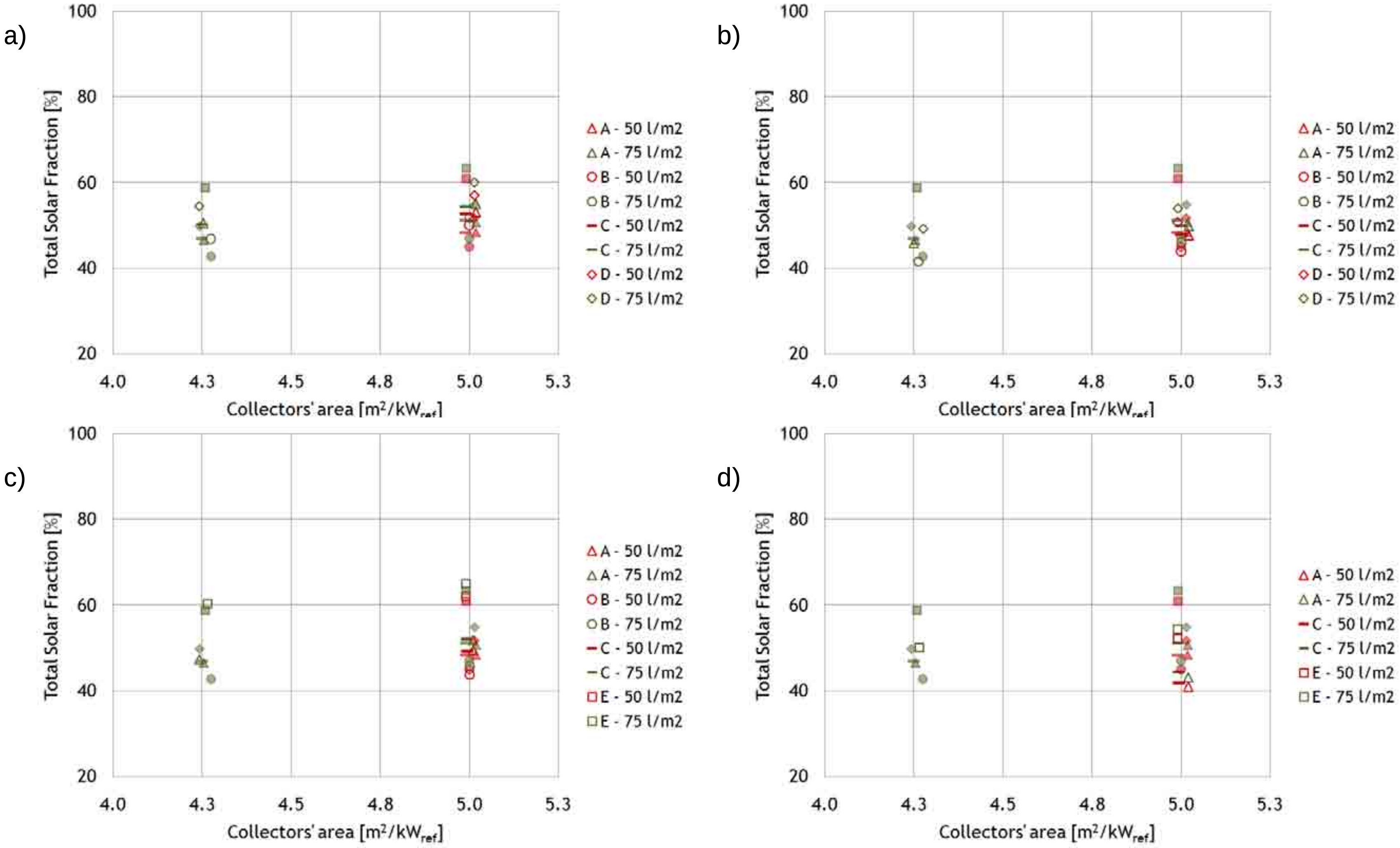


Figure 42 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

8.6.2 Cooling Solar Fraction - Residential

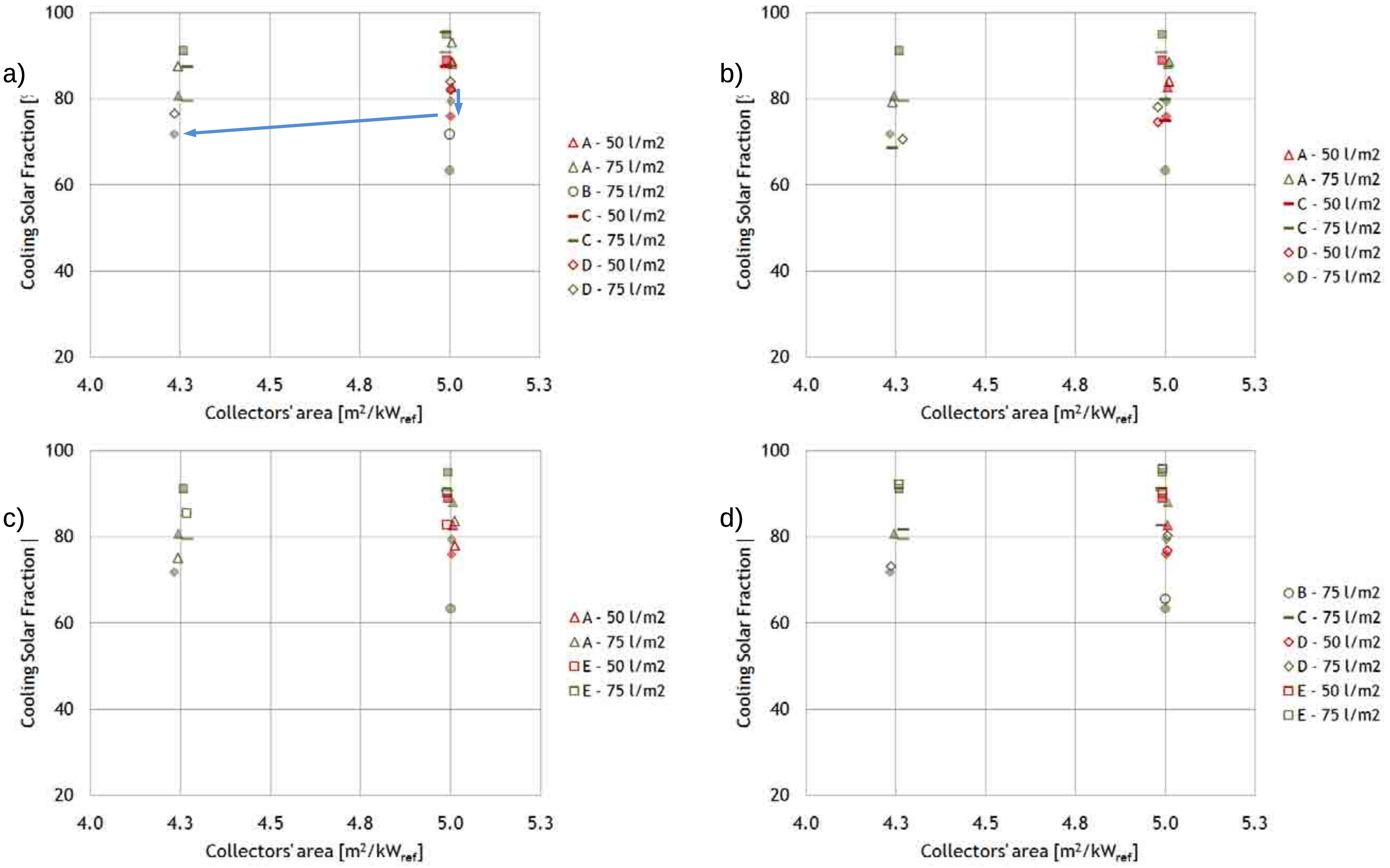


Figure 43 - Naples, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

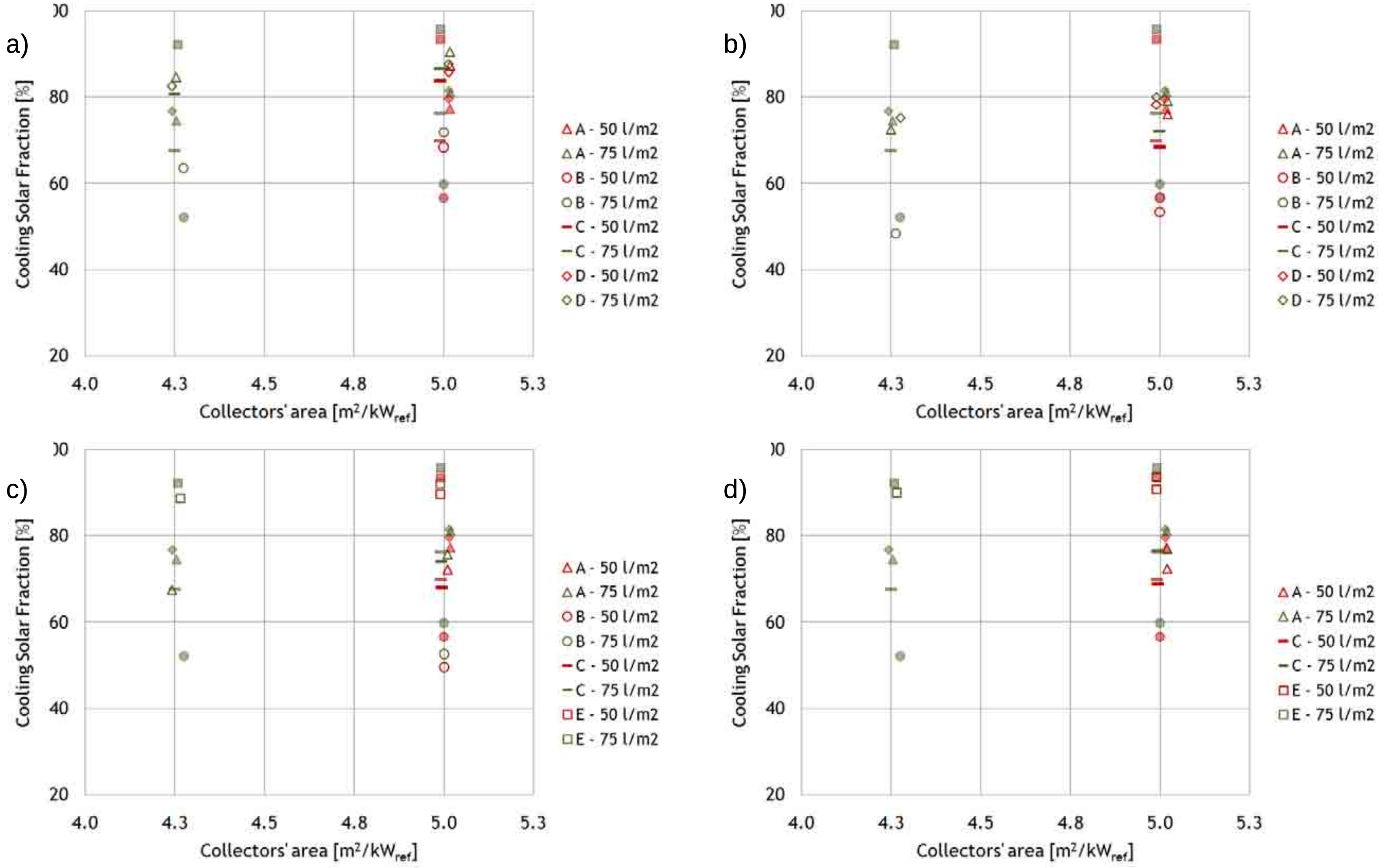


Figure 44 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

8.6.3 Relative Primary Energy Saved - Residential

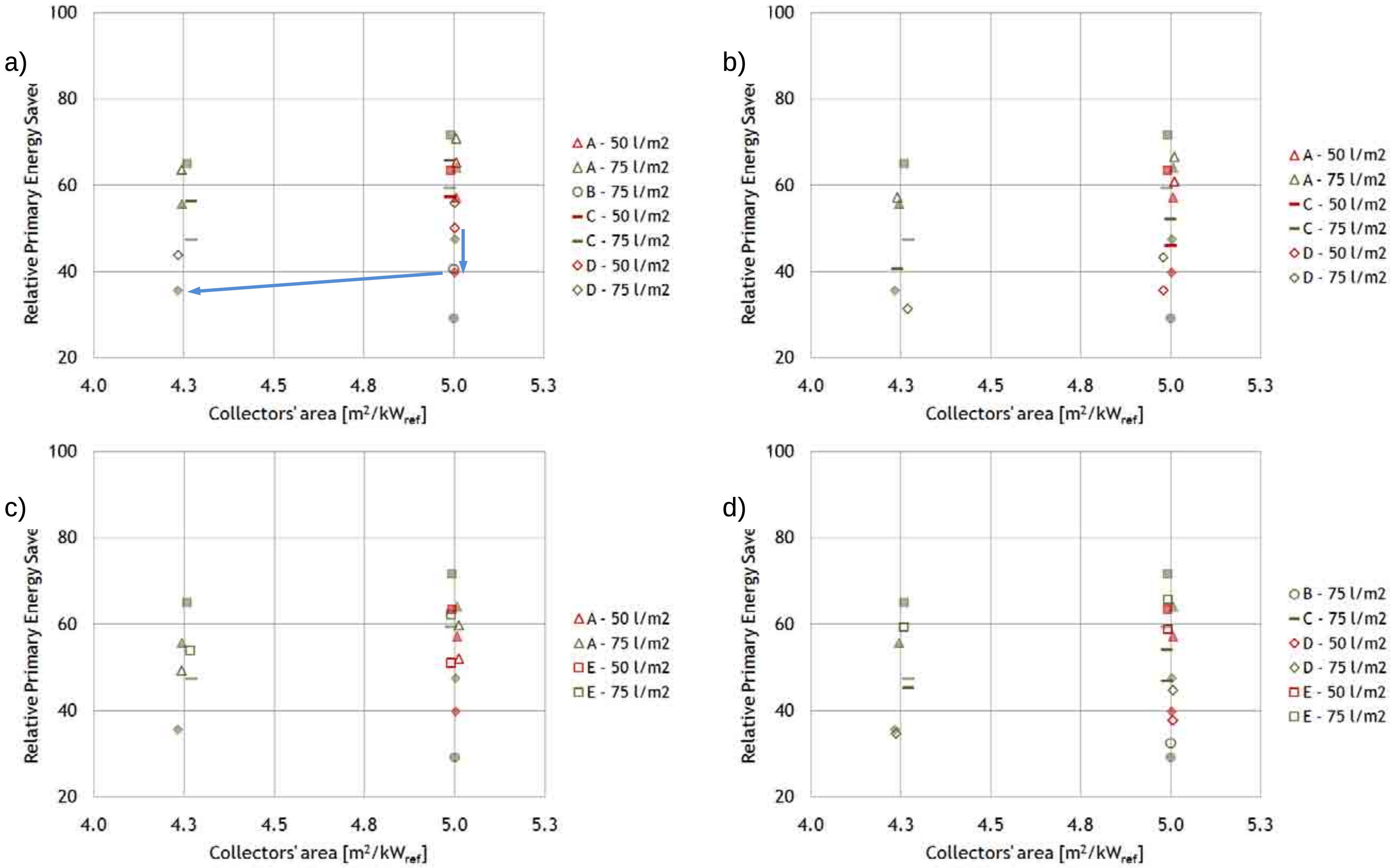


Figure 45 - Naples, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

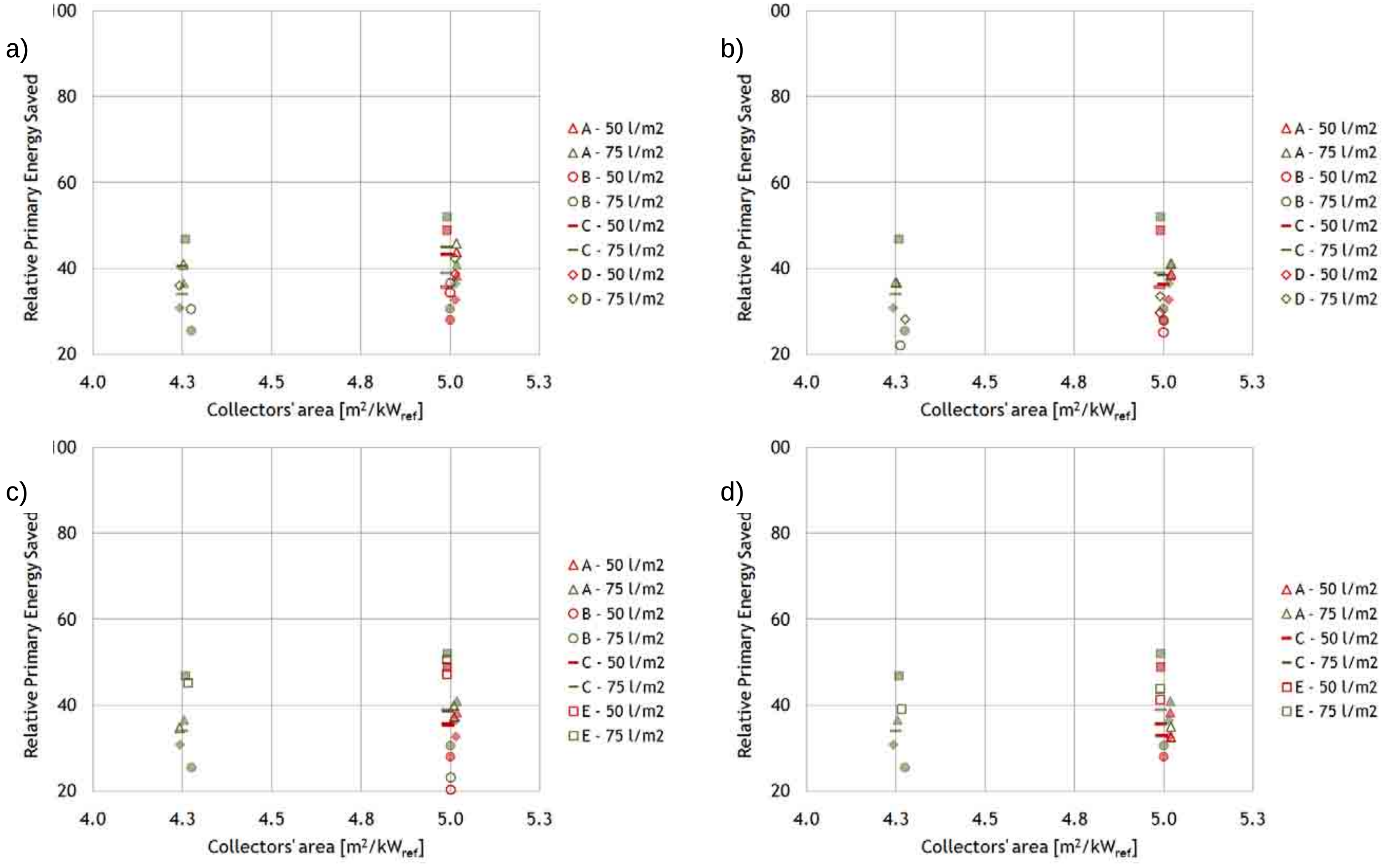


Figure 46 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

8.6.4 Total Electric Efficiency - Residential

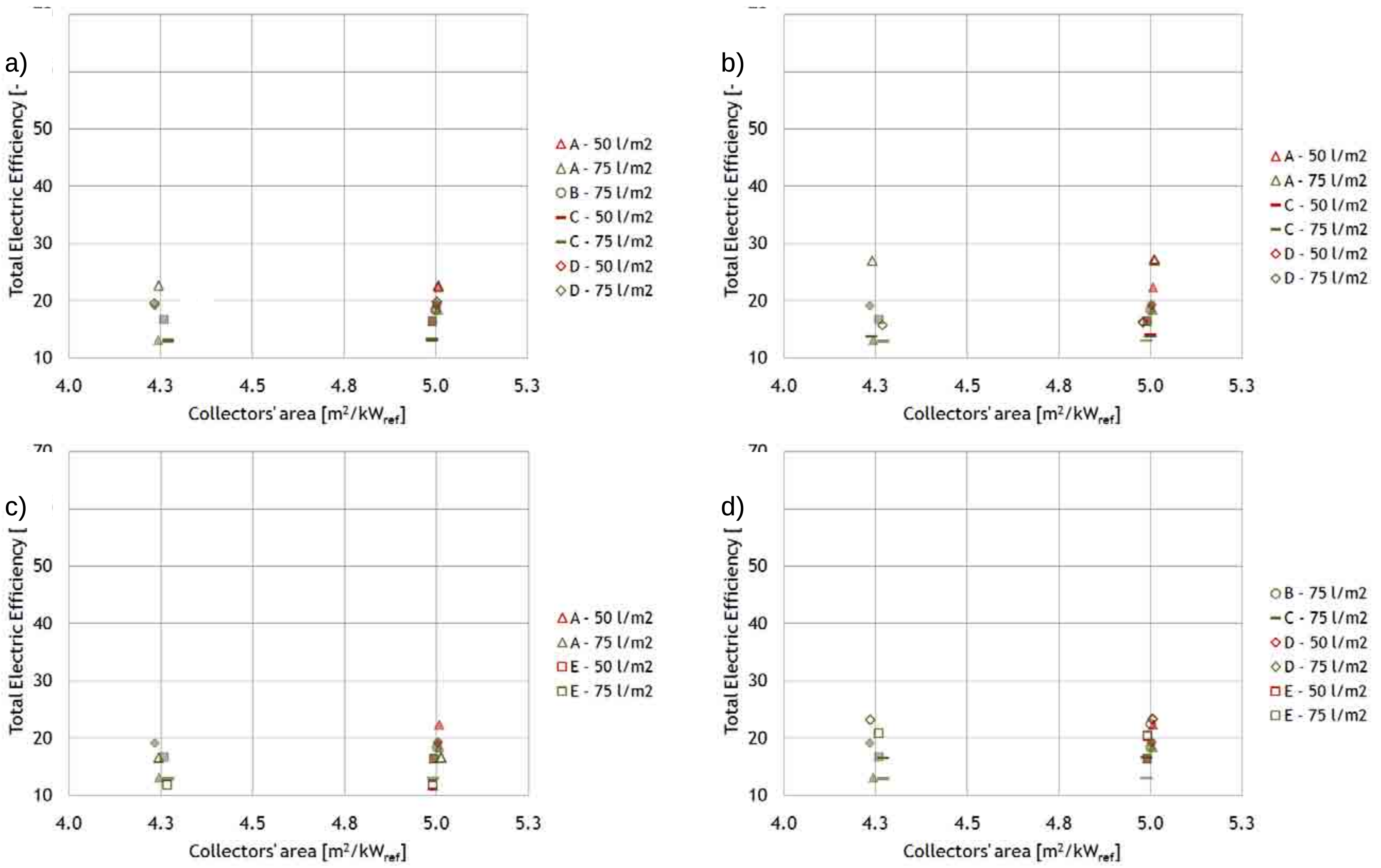


Figure 47 - Naples, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

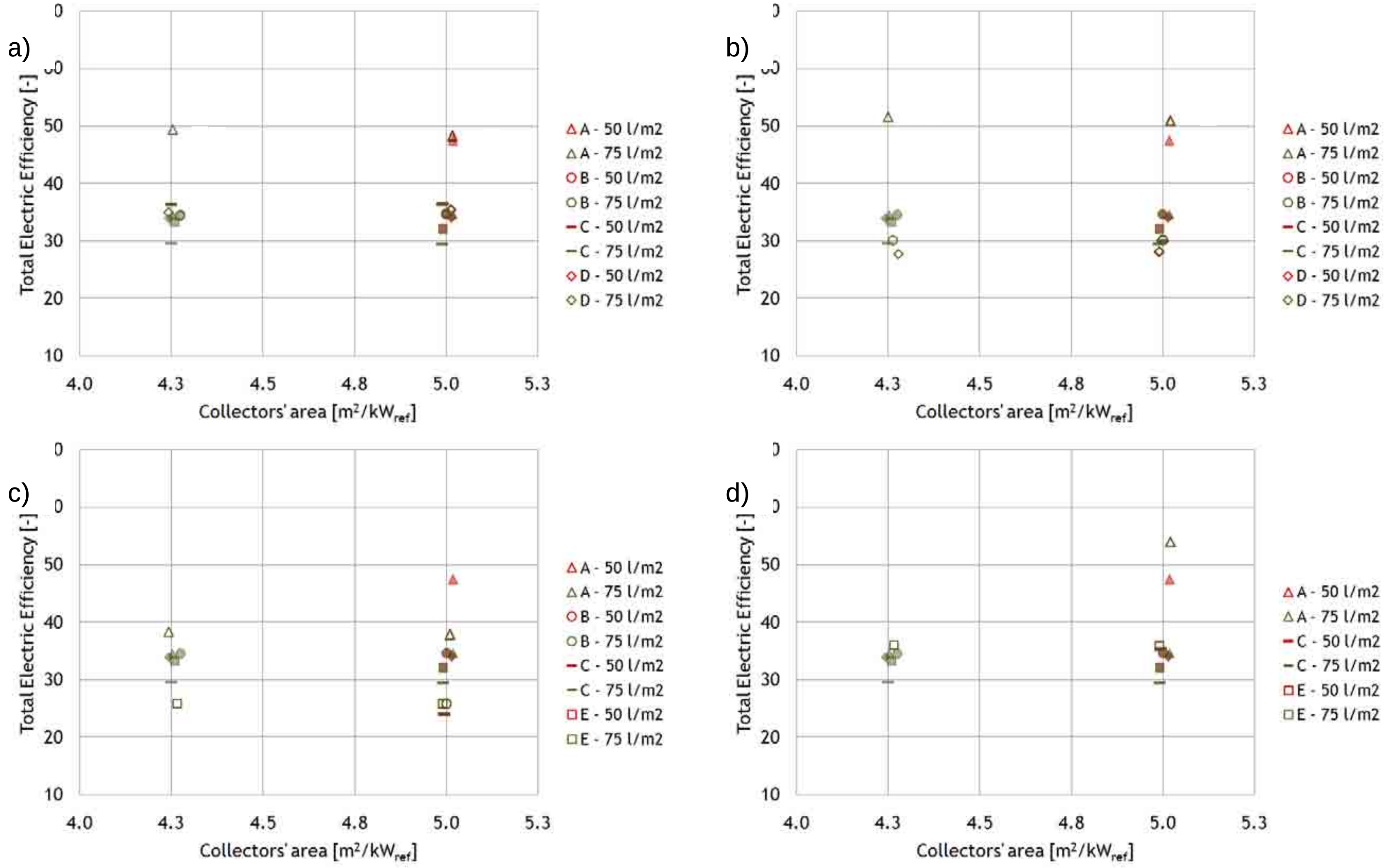


Figure 48 - Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

8.6.5 Gross Solar Yield - Residential

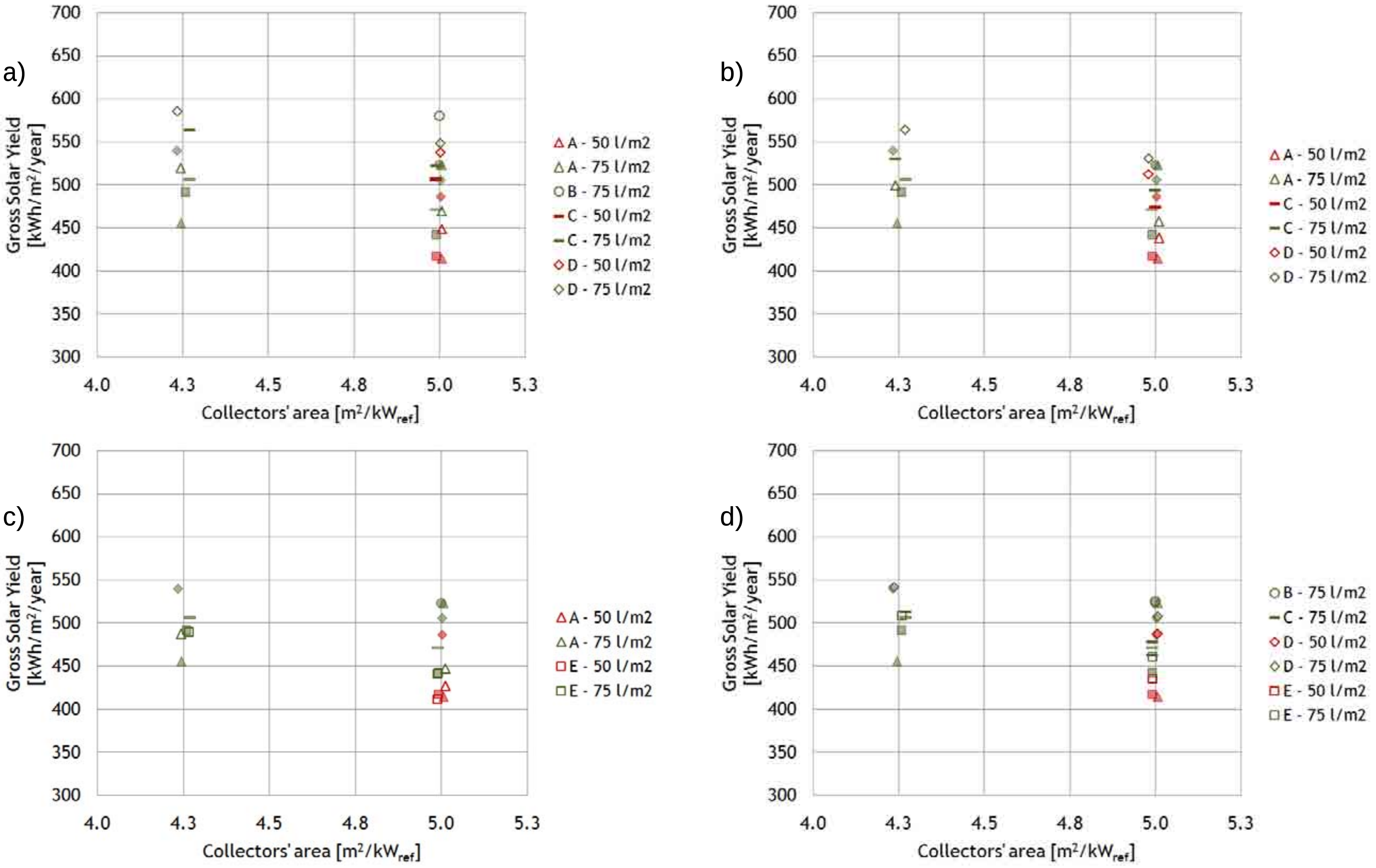


Figure 49- Naples, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

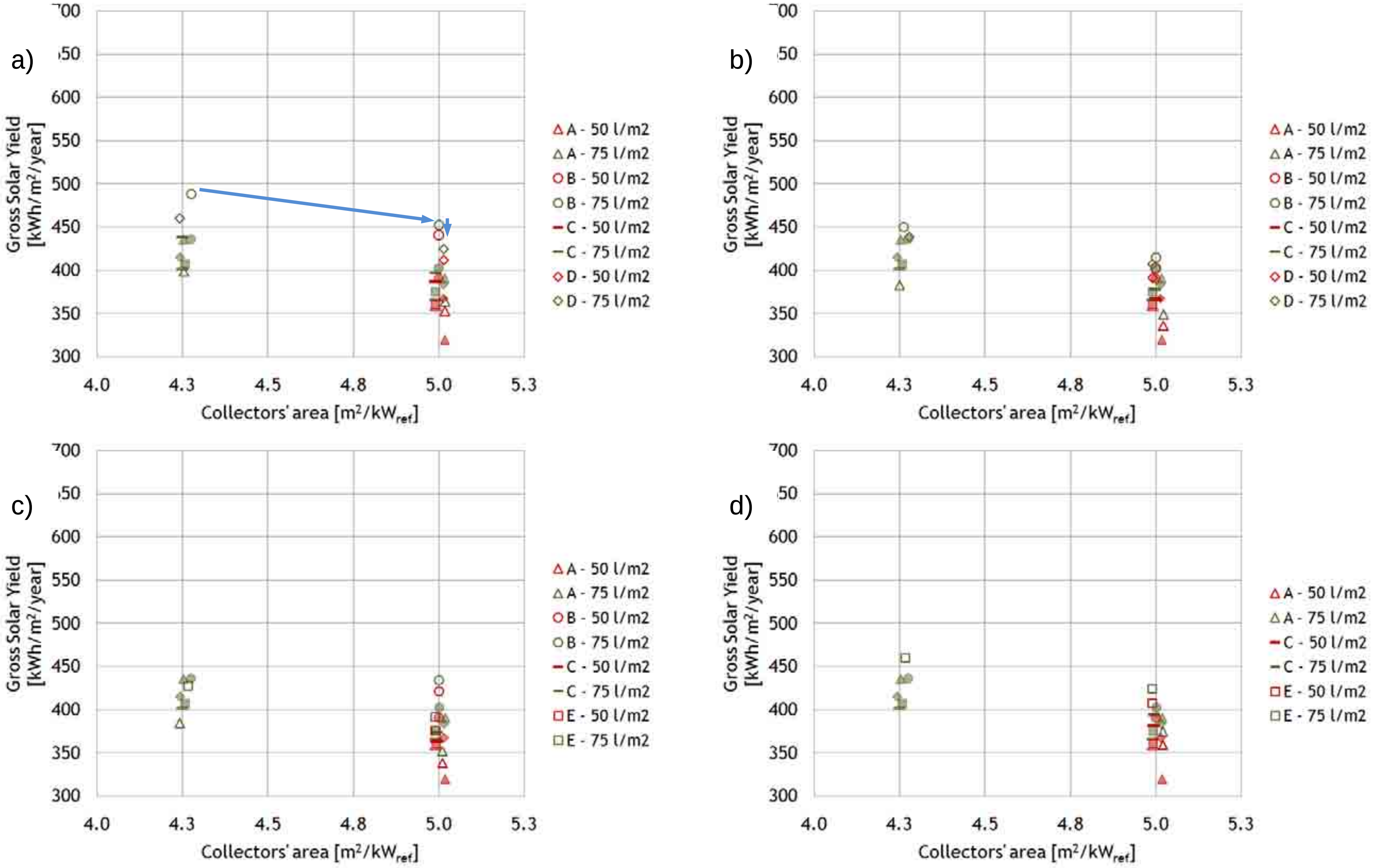


Figure 50 – Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system, c) CC vs FC distribution system, d) R60 vs R100 building

8.6.6 Total Solar Fraction – Office

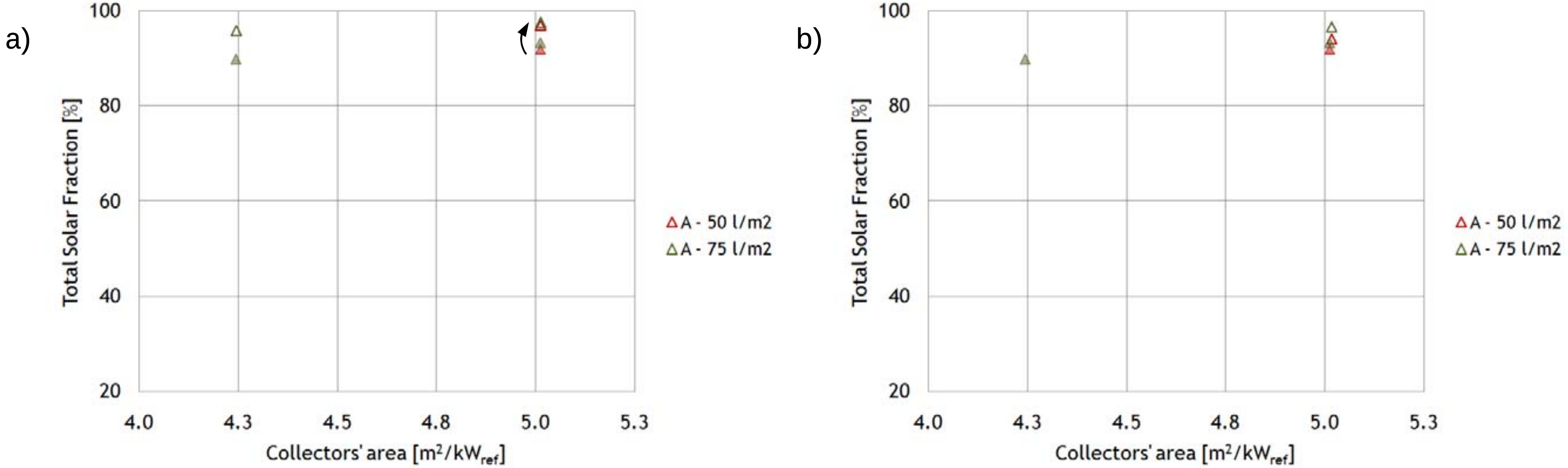


Figure 51 – Naples, a) FP vs ET collectors, b) WCT vs HC rejection system

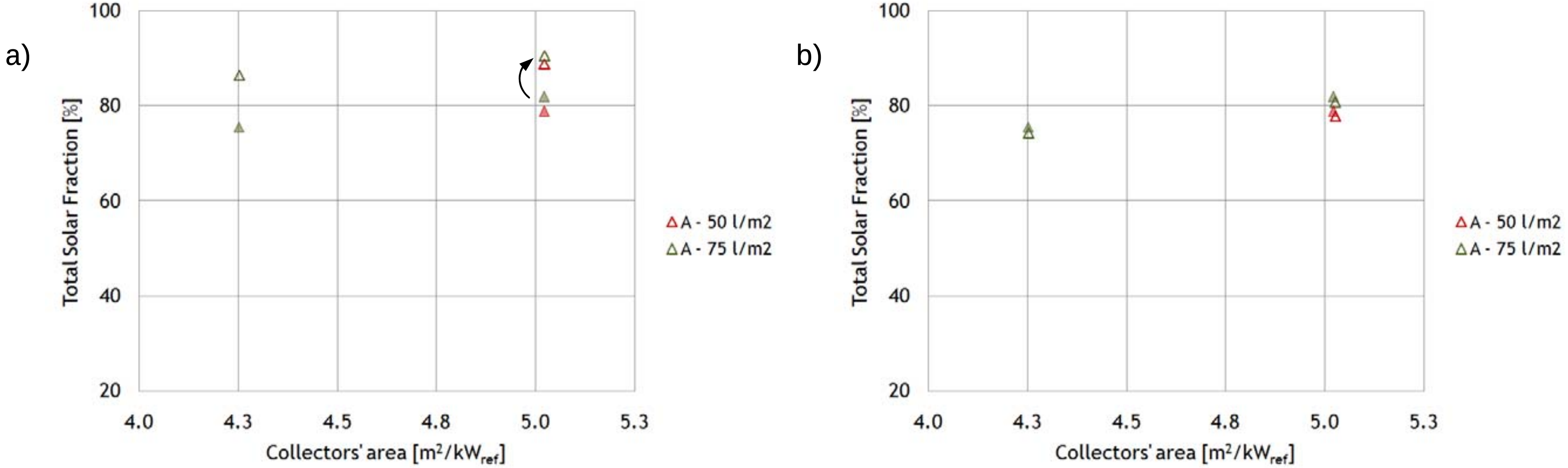


Figure 52 – Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system

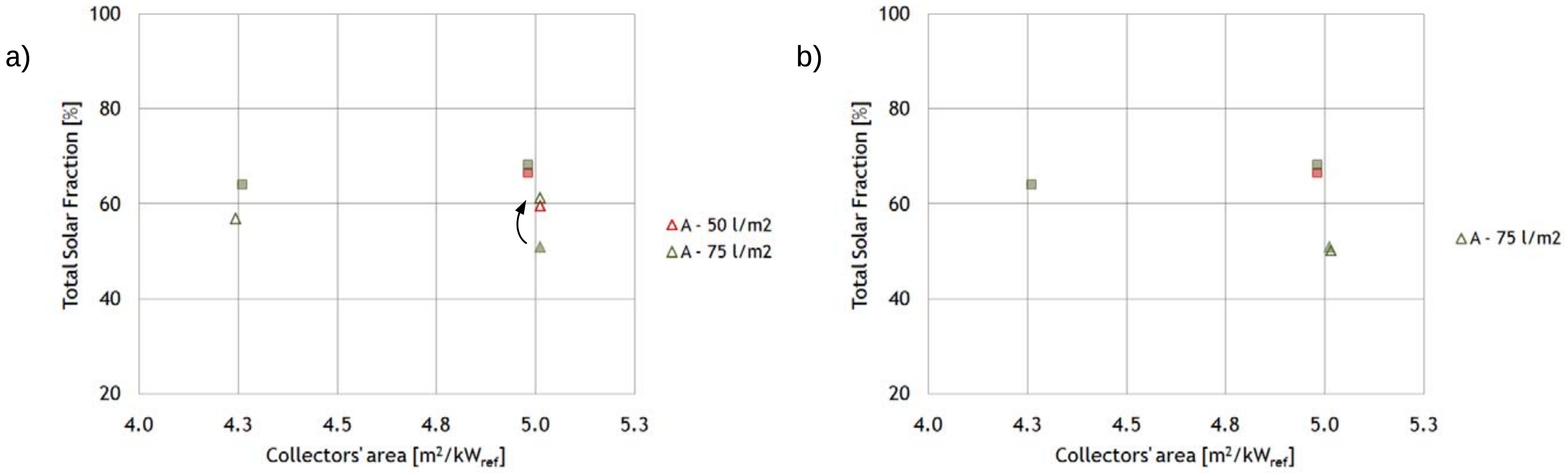


Figure 53 – Strasbourg, a) FP vs ET collectors, b) WCT vs HC rejection system

8.6.7 Cooling Solar Fraction – Office

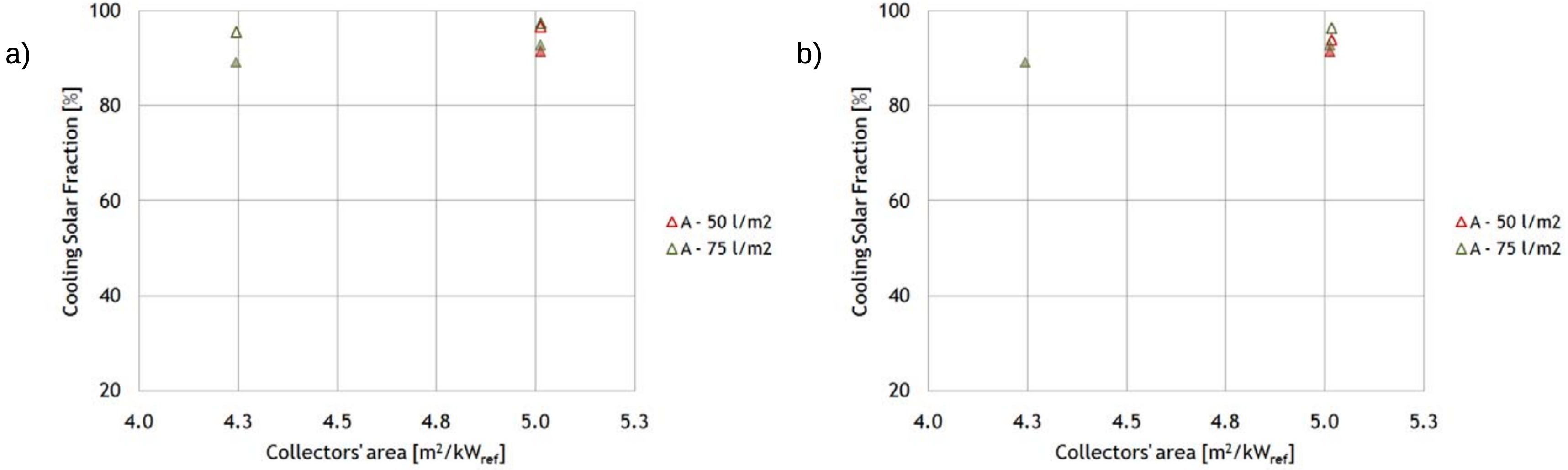


Figure 54 – Naples, a) FP vs ET collectors, b) WCT vs HC rejection system

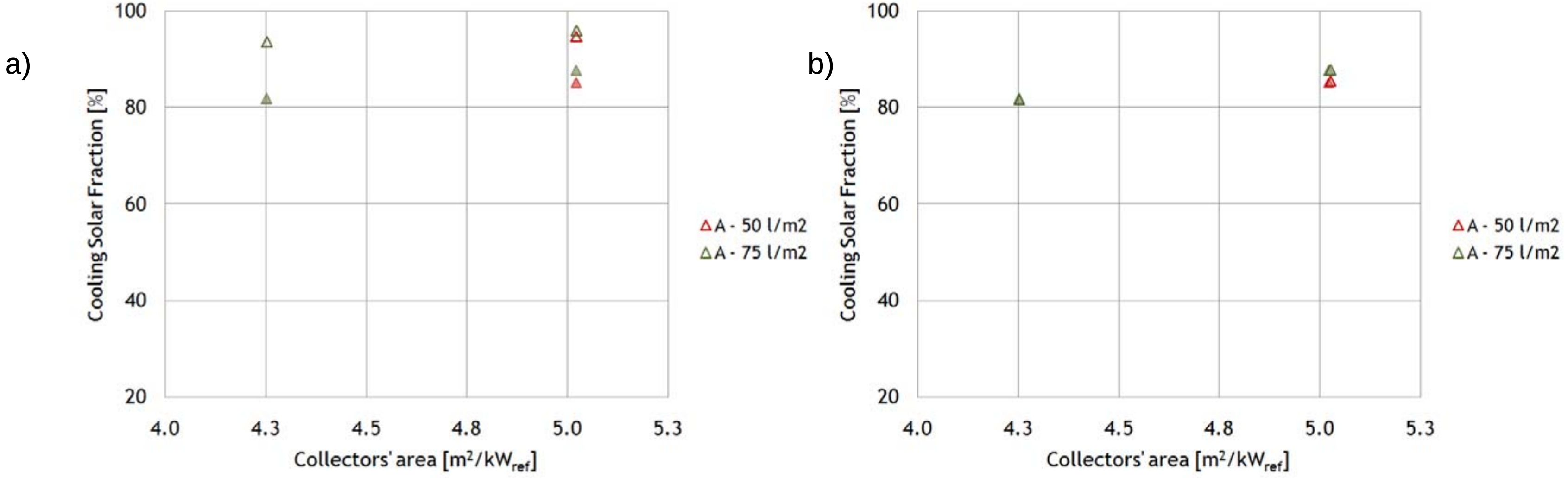


Figure 55 – Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system

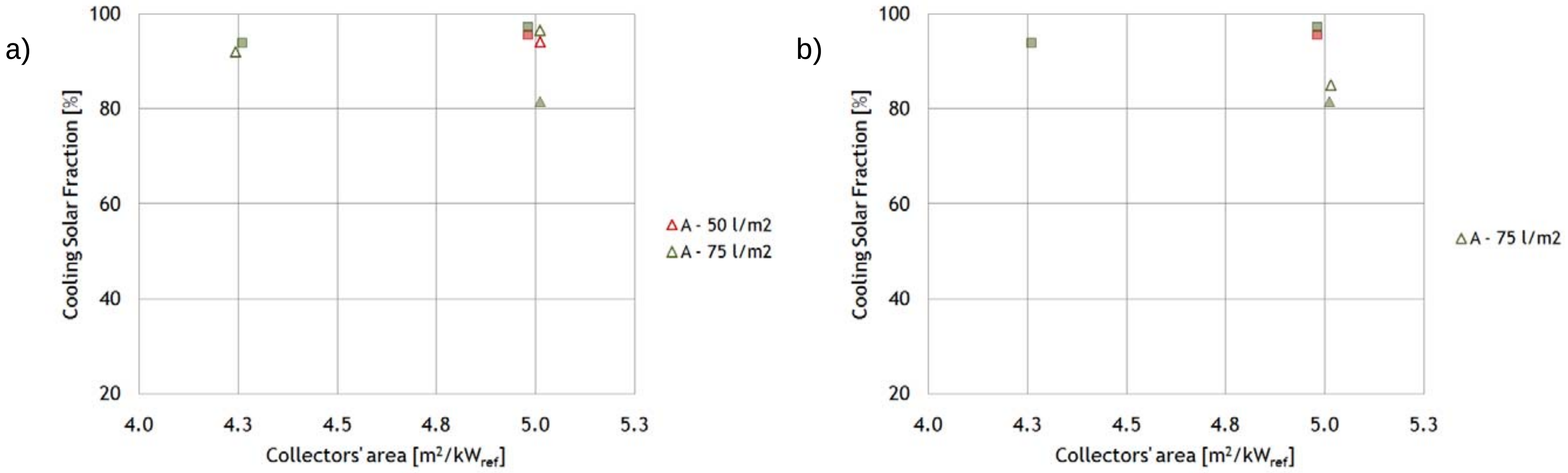


Figure 56 – Strasbourg, a) FP vs ET collectors, b) WCT vs HC rejection

8.6.8 Relative Primary Energy Saved – Office

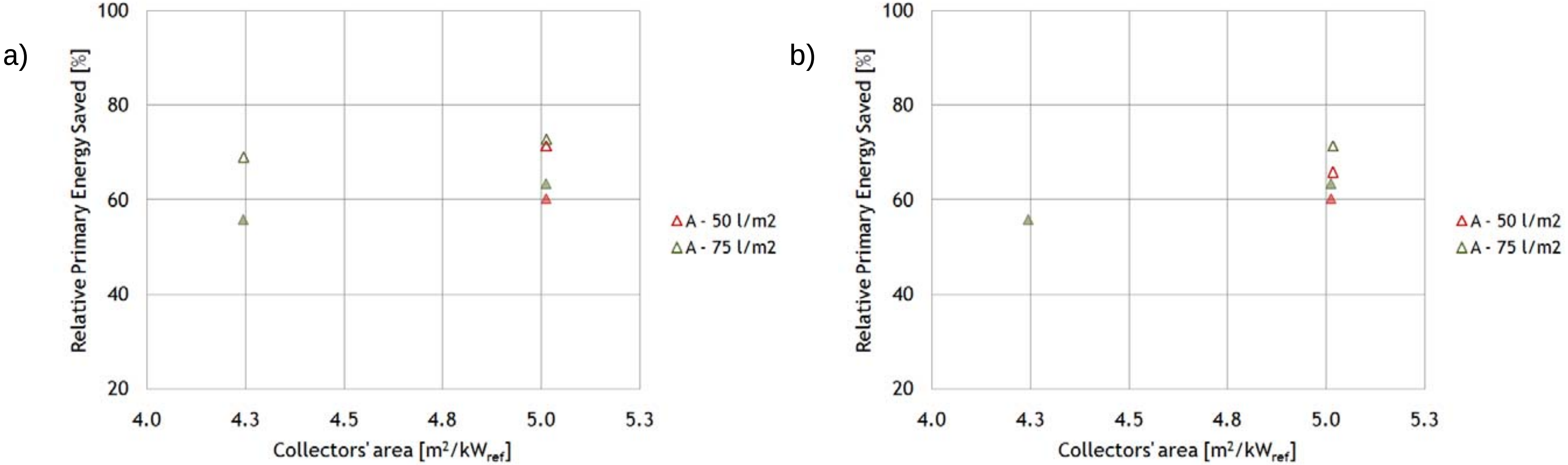


Figure 57 – Naples, a) FP vs ET collectors, b) WCT vs HC rejection system

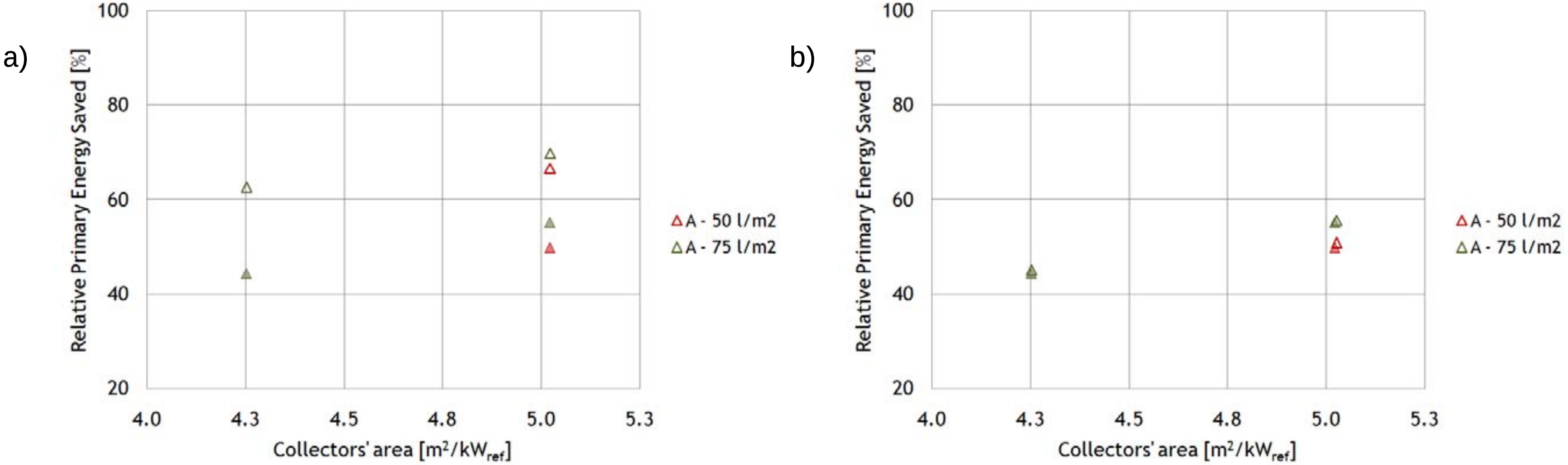


Figure 58 – Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system

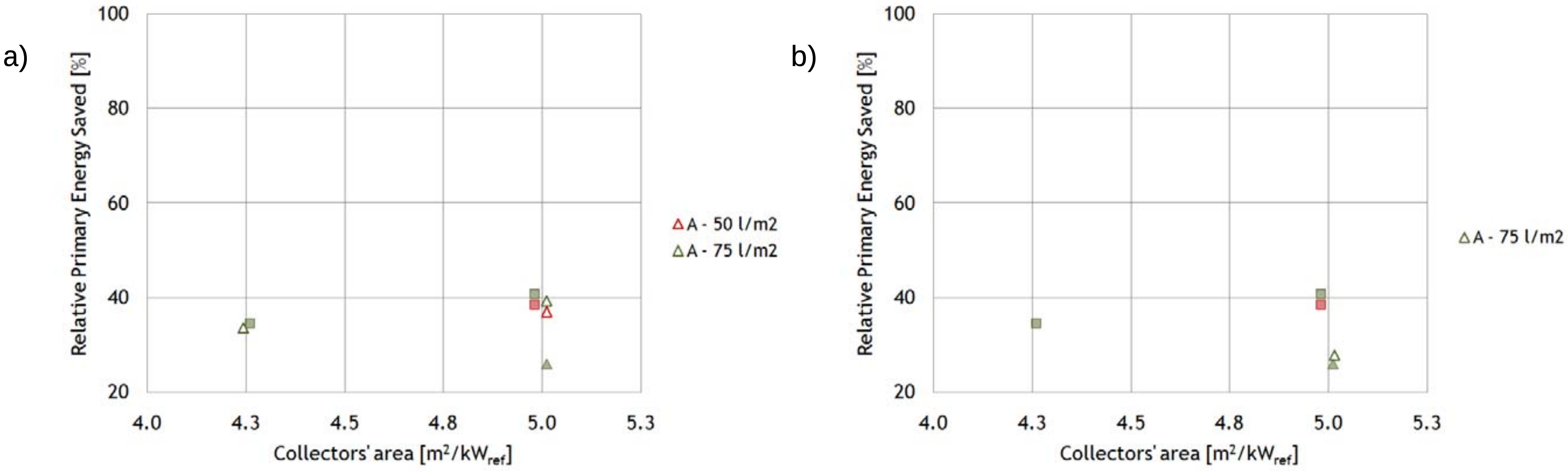


Figure 59 – Strasbourg, a) FP vs ET collectors, b) WCT vs HC rejection

8.6.9 Total Electric Efficiency – Office

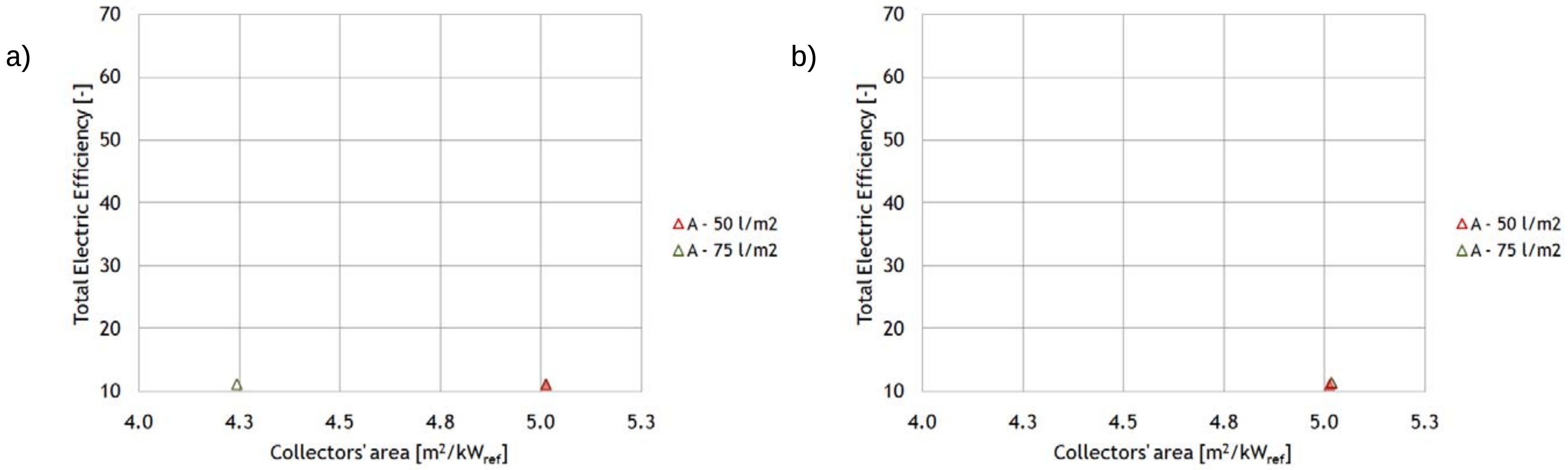


Figure 60 – Naples, a) FP vs ET collectors, b) WCT vs HC rejection system

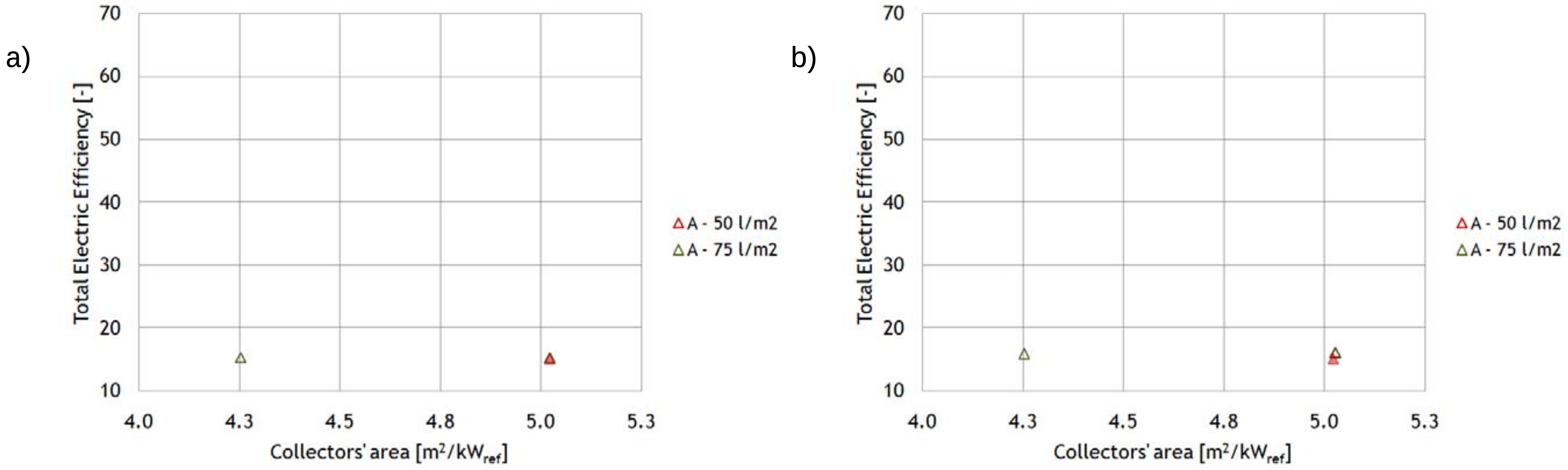


Figure 61 – Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system

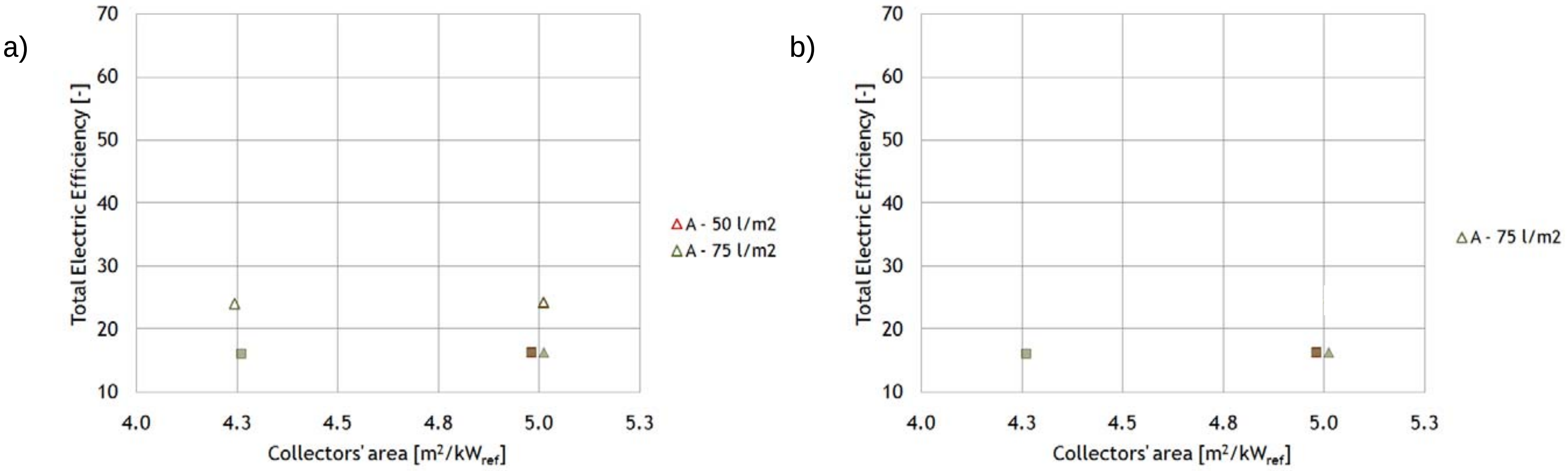


Figure 62 – Strasbourg, a) FP vs ET collectors, b) WCT vs HC rejection

8.6.10 Gross Solar Yield – Office

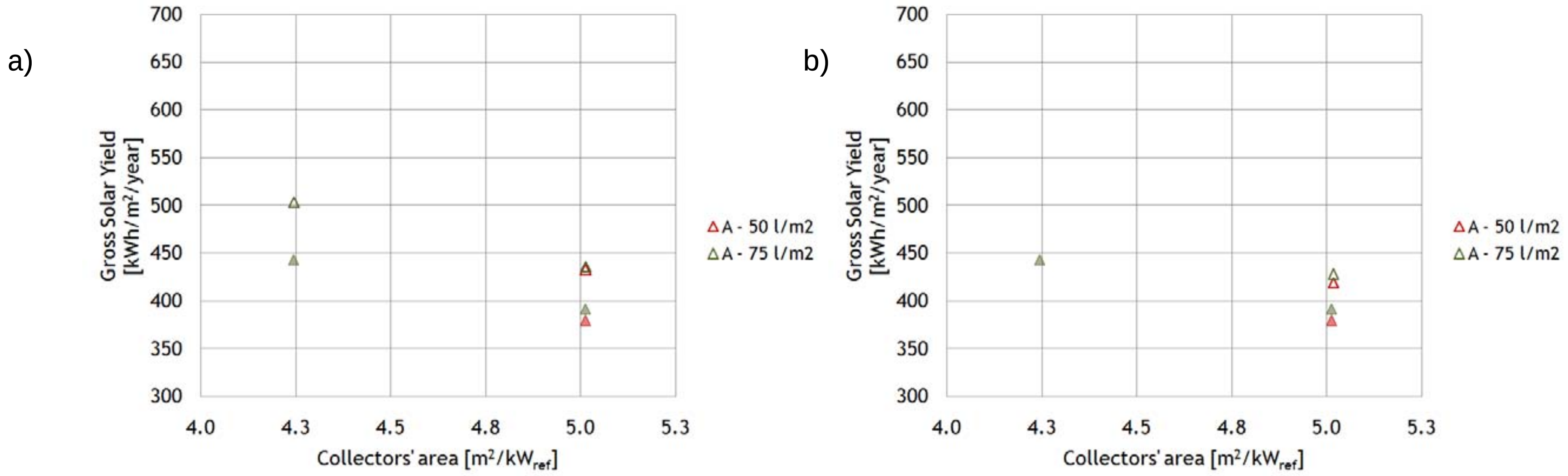


Figure 63 – Naples, a) FP vs ET collectors, b) WCT vs HC rejection system

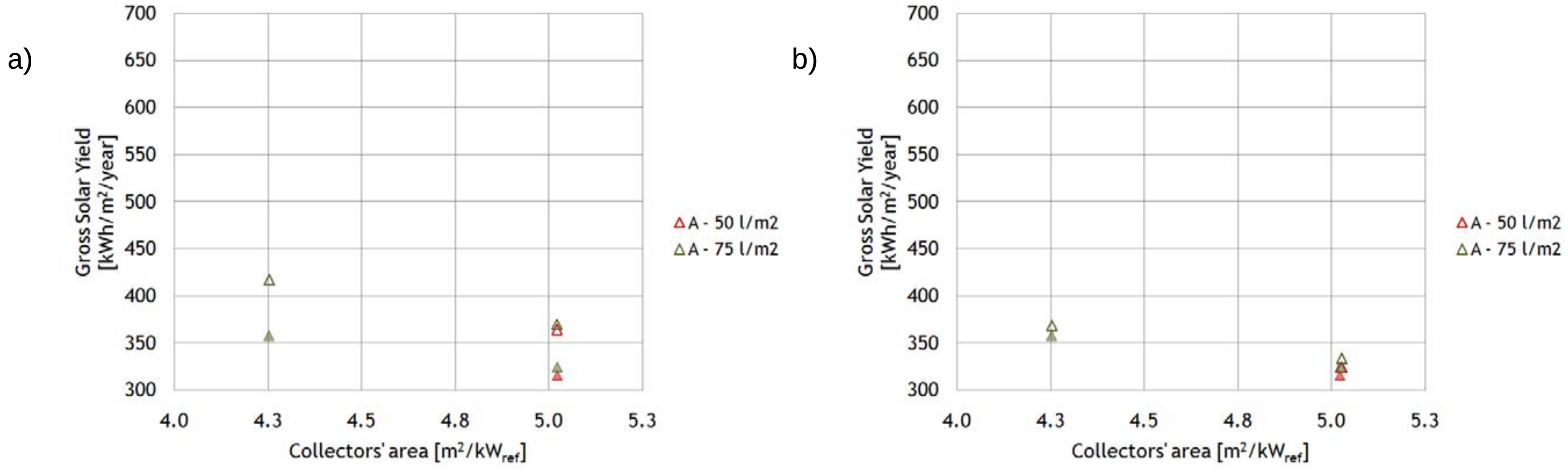


Figure 64 – Toulouse, a) FP vs ET collectors, b) WCT vs HC rejection system

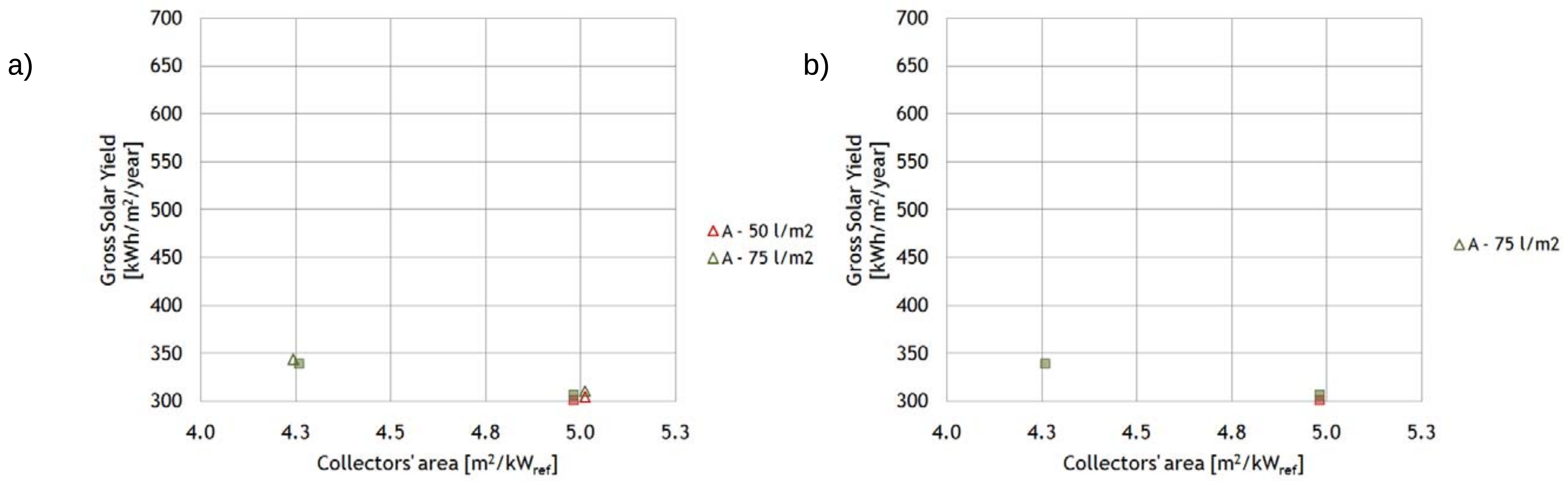


Figure 65 – Strasbourg, a) FP vs ET collectors, b) WCT vs HC rejection